EXTERNAL EVALUATION REPORT

SOIL MANAGEMENT COLLABORATIVE RESEARCH SUPPORT PROGRAM (SM CRSP)

External Evaluation Panel

Eric Craswell (Chair)
Will Blackburn
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Soil Management C R S P

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EXECUTIVE SUMMARY

The External Evaluation Panel (EEP) undertook a series of field visits and meetings in 2006 to evaluate the Soil Management Collaborative Research Project (SM CRSP). The EEP also initiated a survey of SM CRSP stakeholders and 25 of them responded by completing a detailed questionnaire. The results of the survey and the deliberations of the EEP confirm that the SM CRSP has had significant impact on agricultural training and education, and on outreach and adaptive research in the extensive rice-wheat regions of South Asia, and on the maize areas of Southeast Asia, West Africa and Latin America.

The SM CRSP research was strategic in providing products that were both practical and universal in helping farmers move from subsistence to intensified agriculture. The results can be summarized as follows:

Decision-support tools that reduced investment risks and increased returns:

- Nutrient Management Support Systems allowed field agents, backed up by soil test kits and soils lab, to provide quick and accurate assessments of plant nutrient requirements. These systems were tested and used in Mexico, Honduras, Nicaragua and Panama in Central America; in the Philippines, Thailand, Laos and Timor-Leste in Asia; and in Mali, Senegal, Ghana, The Gambia, Mozambique and Angola in Africa; and

- Trade-off Analyses allowed multidisciplinary teams to more effectively work together to develop strategic policy and tactical management support on questions of carbon sequestration in Senegal, Mali and Ghana; and on questions of nutrient management in Kenya, Uganda, Ecuador and Peru.

Technologies that reduced risks and increased productivity for smallholders:

- ACN or ridge till technology showed enormous potential to increase water retention in soils of semi-arid West Africa, specifically Mali and Senegal (in each case poor rural women are the main beneficiaries);

- Innovative technologies at the farm level in the rice-wheat system of Nepal and Bangladesh. Examples include the raised bed technology for vegetable production and healthy seedling technology that is becoming widely adopted in parts of the rice-wheat belt in South Asia; and

- Site-specific crop management designed to improve production efficiency and reduce environmental pollution in maize and rice systems in Thailand, Laos, the Philippines, and Timor-Leste and in Timor-Leste helped establish an export candlenut oil industry.

Research approaches developed for assaying bean plants with better root systems and for identifying the effects of genetically modified crops (GMO) on the soil biota:
The latter research results indicated a lack of soil ecological impacts of the Bt gene and filled a major knowledge gap on the environmental effects of GMOs.

The SM CRSP has contributed to at least three objectives in the new USG Country Level Foreign Assistance Framework. Local governance was strengthened as people organized themselves around land management issues to do things as members of a local group that they could not do as individuals. The environment was positively affected as the technologies and decision-support tools helped people create natural capital, reduce erosion and reduce pollution. And, livelihoods were improved as the technologies and decision-support systems provided people with more profitable agriculture as well as new sources of incomes.

Finally, we also saw remarkable cases where national and international institutions were strengthened.

The EEP results indicate that the SM CRSP was highly successful in providing the proof of concept for critical Decision-Support Tools, soil management technologies and GMO research approaches. The results also indicate that the number of actual beneficiaries is small compared to the potential number of beneficiaries. Scaling up the number of those beneficiaries and getting full returns from the USG investment in the SM CRSP will require follow-up with SM CRSP's partners. The challenge will be to provide this support during the hiatus between the scheduled end of the SM CRSP (2007) and the start-up of the planned Soils, Water and Ecosystems Services CRSP (2009). Losing momentum during this period would likely put the brakes on helping smallholders move forward and would reduce returns to US taxpayers' investments.

Introduction

The Bureau for Economic Growth, Agriculture and Trade (EGAT) of USAID commissioned the external evaluation reported herein. The current grant of the Soil Management Collaborative Research Project (SM CRSP) will come to an end on September 30, 2007. The general responsibility of the External Evaluation Panel (EEP) was to assess accomplishments and progress leading to individual project objectives and to determine the collective contributions of these projects in achieving the objectives of the SM CRSP's global plan. To complete this task, panel members performed a desk review and then made selected on-site inspections of individual Phase 2 projects to assess their current and potential impacts. Moreover, the EEP designed a survey that was sent to SM CRSP participants, whose replies, in confidence, are summarized in Appendix II. In concert with this evaluation, the EEP also considered future soil management needs and recommend priorities for future investments in soil management research and education. This EEP report presents the Panel's findings and provides recommendations to USAID. These are designed not only to have some impact on the last year of the SM CRSP projects, and any bridging extension developed for 2008-2009, but also to hopefully feed into making the next generation of SM CRSPs even more effective, particularly those dealing with soil and water management.

History

Improvements in agricultural performance and natural resource management have occurred at a rate too slow in the past to keep pace with population growth. Over the past several decades, USAID has provided leadership to reverse this situation by transforming the slow trial-and-error methodology into a faster-paced, science-based development process. In the 1970s, USAID initiated a new project called the Benchmark Soils project in which technology transfer on a global scale could be achieved by means of science-based analogy. This project demonstrated that successful crop production technology could be transferred from its site of origin to other locations in the world where soil and climate were similar or analogous. This USAID project gave impetus to the development and refinement of the FAO Soil Legend and the USDA Soil Taxonomy and its methods of making and interpreting soil resources inventories on an international scale have enabled technology transfer by analogy possible today.

In 1983, USAID established a follow-up project to the Benchmark Soils project called the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) project. Using systems simulation, the project made technology transfer by analogy much more powerful by enabling users to

transfer knowledge and technology not only to analogous sites, but also to any site where information about soil and climate data were available. The USAID-funded IBSNAT project brought together agricultural systems modelers from Europe, Australia and North America to produce a decision support systems capable of simulating yields for the major food crops, including wheat, rice, maize, sorghum, millet, soybeans, *phaseolus* bean, peanut, taro, cassava and potato, anywhere in the world. The decision support system used globally today is called DSSAT, for Decision Support System for Agrotechnology Transfer. The strength of systems simulation is its ability to let the user evaluate outcomes and risks of alternative management practices, thereby enabling him/her to explore the future and exercise choice.

In the 1980s, USAID also initiated the Collaborative Research Support Programs (CRSP), one of which focused on soils. Under this program, knowledge-based tools called expert systems or knowledge-based decision aids were developed. With these tools, knowledge needed by users, ranging from extension agents to policymakers, could be captured, condensed and organized and made accessible to others.

Over the past few decades, computers have matured from being able to simulate a single crop cycle from planting to harvest in several hours to simulating 25 years of crop growth in seconds. Moreover, remote-sensing satellite technology can detect objects less than a meter in size, laboratory methods can analyze samples automatically and software enables users to instantly solve problems that required weeks or more to examine in the past.

The current SM CRSP is built on the foundation of these and other past accomplishments. Its aim is to enable agricultural productivity and sustainable natural resources management to keep pace with human aspirations and population growth.

A major endeavor of the current SM CRSP is to institutionalize science-based decision making in developing countries by combining capacity building with research and development activities. This report reviews the SM CRSP's accomplishments in this context.

EVALUATION OF COMPONENT PROJECTS

The Nutrient Management Support System (NuMaSS)

Principal Investigators: (1) T. Jot Smyth and Deanna Osmond, North Carolina State University; (2) Russell Yost, University of Hawaii, Tasnee Attanandana, Kasetsart University and Madonna Casimero, Philippine Rice Research Institute

The Nutrient Management Support System (NuMaSS) is an interactive software program that provides users with options for crop-soil fertility management. Outputs of NuMaSS are the product of calculations based on long-standing, scientific, crop-soil fertility relationships. NuMaSS, however, is also dynamic in that outputs can be tailored for any size and number of agricultural domains by adjusting inputs and software parameters based on field-specific information. The combination of science-based and domain-specific information introduces qualities of stability, resilience and equitability not found in either more empirical, statistical or theoretical approaches.

For historical geographical and financial reasons, the NuMaSS project is managed as two sub-projects by two principal investigators. One sub-project focuses on Latin America and the other on Southeast Asia and West Africa. Project objectives are identical and for review and impact evaluation the NuMaSS project will be considered as one integrated project.

Project Objectives

1. Test and compare NuMaSS predictions of nutrient diagnosis and recommendations with existing soil nutrient management recommendations and practices.
2. Identify and refine NuMaSS components that limit adoption and impact.
3. Monitor use of NuMaSS and develop auxiliary tools to help users make better use of the software knowledge in their decisions about nutrient management.

Project Accomplishments

Southeast Asia

- Crop yields have been shown to increase based on NuMaSS recommendations. In Negros Occidental, Philippines, yields are increasing from 1 to 3 tonnes of maize/ha to 7 to 8 tonnes with better cultural practices, choice of varieties and use of lime and fertilizer as recommended by the NuMaSS software. Limestone is now a commercial product widely available for managing the acid soils of Isabela province, Philippines. No lime was commercially available in 1997, when the project began. Producers living or only having land in the previously termed "undifferentiated uplands" now have cropping options, beside upland rice, that provide cash and food, including peanut, maize and mung bean which were considered impossible before. This new area comprises an estimated 5.5 million hectares and extends over nearly all islands and many provinces of the Philippines. In Thailand, site-specific agronomic technologies using NuMaSS have been applied to rice, maize and sugarcane with excellent results. In Region 2 of Northern Luzon, 2,700 farmers are using NuMaSS recommendations. The area in maize to which NuMaSS recommendations can be directly applied is 32 percent of the Maize production area of the Philippines or 780,800 hectares, according to PhilRice and DOA statistics.

- Significant formal training has been carried out under the auspices of the NuMaSS project.

This ranges from five Ph.D. candidates who are near completion to five MSc. students to close to 1000 Thai farmers trained in site-specific nutrient management technologies. In addition, ten Lao farmers and technicians have been trained, and in turn trained at least 50 more.

- The NuMaSS software has been adapted for a PDA platform and is available in Thai, Spanish, Portuguese and two local dialects. Numerous quality publications have been written and distributed describing the various aspects and components of site-specific nutrient management.

- NuMaSS provides economic as well as fertilizer analysis that is an advantage when farmers use the NuMaSS as a decision aid tool. NuMaSS has been proven to be comparable or even better than the current regional recommendation as it takes into account the long-term sustainability of the upland areas in terms of ameliorating the acidity of the soil. Yields were either comparable or higher than the regional recommendation and the current farmers' practice.

- Robust, multinational networks that drive south-south collaboration have been created. The networks add value to the formally-trained collaborators. Exchanges between Thai and Lao researchers, as well as farmer-to-farmer visits, have occurred. Thai and Philippine networking has resulted in the transfer of the Thai-developed, farmer-oriented pocket guide for soils identification. The Thai-developed field soil-test kit has been adopted in Timor-Leste as well as in West African countries. The participatory approach adopted by NuMaSS has been a key element of its success, especially in promoting the role of farmer leaders in the application of the soil test kit and NuMaSS.

West Africa

- As in Asia, capacity building is a major activity in West Africa. Two students are studying at the University of Hawaii while carrying out their field research, which takes place in Mali and Senegal. A third scientist is studying for his MS at the University of Hawaii, using a grant he received from the International Institute for Research, Sweden. Workshops and farmer-to-farmer visits of more than 300 farmers were conducted.

- In Angola a soils, plants and water diagnostic laboratory has been equipped and staff trained through a cooperative effort of the SM CRSP and World Vision. This is effectively the first soil, plant and water analysis laboratory in the country since the war 30 years ago. The first samples were analyzed in 2005. Now the laboratory can analyze them on a regular basis. The laboratory provides the first diagnostic support for the World Vision fertilizer trials on food crops maize, potato and field beans.

- Through the global NuMaSS network, the Thai soil test kit has been adapted and adopted in Angola and Mozambique. Approximately 100 units have been distributed, and over 30 NGOs in Mozambique have been introduced to the kit.

Latin America

- In field testing, NuMaSS recommendations have proven superior to current practices in two ways: 1) yield increases based on identification of limiting nutrients, and 2) reduced fertilizer applications without compromising yields. Regions and countries involved include Tamaulipas Province—Mexico; all regions—Honduras; northwestern region with crystalline mineralogy—Nicaragua; Veraguas, Azuero Provinces—Panama; Cochabamba Province—Bolivia; and Pará State—Brazil.

- Version 2.2 of the NuMaSS software is being finalized and will have an improved Data Table Editor Module that will greatly facilitate creation of customized regional data tables. The version will be available in English, Spanish and Portuguese.

- Revitalization of soil and plant testing laboratories in Honduras, Nicaragua and Panama. Central American countries once had a strong multinational network of soil testing laboratories due to the efforts of the USAID's International Soil Fertility Evaluation and Improvement Project or ISFEIP. After the project ended, the collaboration and quality of soil testing rapidly collapsed. The labs are once again functioning and collaborating. In a survey of labs in Honduras-Nicaragua that served public clients, none of them could provide experimental field and lab data to substantiate their fertilizer recommendations for N or P. Through their collaboration with the SM CRSP project they are gaining exposure to field and lab data from experiments designed to identify fertilizer N and P requirements of soils and crop specific to the regional domains they serve. They are also verifying the utility of NuMaSS in formulating site-specific and economically viable fertilizer recommendations.

- An estimated $500,000 in NuMaSS resources has been leveraged to an estimated $800,000. Notable examples include five FAO-funded NGOs working in Honduras, which are funding their own farmer field validation trials. Also in Honduras, a private fertilizer company is financially supporting the testing of NuMaSS. In Bolivia, a potato seed producer organization in Bolivia is funding NuMaSS trials.

Project Assessment

The NuMaSS project is most relevant regarding the strategic theme of food security, with a focus on increasing agricultural productivity. As noted by a respondent to the Survey, "[NuMaSS] is very relevant in terms of providing a decision tool for site-specific nutrient management. …This simplified guide has translated scientific terms into layman's language within the reach of extension workers and even farmers." Another respondent noted its timeliness in terms of providing a tool for areas where demand for cash crops is growing, "The project is very relevant considering that the provincial government of Negros Occidental is boosting its corn production to meet the demands for livestock and poultry industry." Another noted that demographic pressure would push agriculture into more marginal zones where people will need a tool like NuMaSS to help make the best decisions.

Relevance can inspire innovation and the Thai field soil test kit and the farmer-oriented pocket guide for soils identification are examples. Thailand is committed to improving agricultural productivity through intensifying site-specific management. NuMaSS mobilized Thai collaborators whereby they developed materials and methods for obtaining NuMaSS inputs on site, in farmers' fields, thereby eliminating the time lag of sending soil samples to a testing lab. In addition, Thai collaborators have integrated several NuMaSS algorithms into their crop simulation decision support software for corn, rice and sugarcane. By its relevance, NuMaSS mobilized this innovation.

In Central America, NuMaSS has been the motivation for rebuilding the multinational soil and plant testing laboratory network. Because it is science and knowledge-based, NuMaSS has given a sense of professionalism to agronomists working in the public sector, the private sector and NGO aid organizations.

The majority of the questionnaire respondents judged the NuMaSS's **quality** as high. A measure of high quality and relevance of a

technology is the recognition by others of its value. Several examples of others investing in NuMaSS were noted by respondents. A particularly potent example was its being honored with an award from the Office of the President of Mexico as being one of the top ten technologies in Mexico in 2006. Relevant research results and educational materials are written-up on a timely basis. Particularly notable are the efforts of Kasetsart University in Thailand. Perhaps the most impressive aspect of these publications is the range, from meticulous soil-science component research to lessons teased out from participatory research with farmers on site-specific nutrient management. The speed with which research results are reported is commendable.

Some respondents noted that NuMaSS's adaptive research approach raised both the relevance and quality of the work. Working directly with farmers provided reliable data.

The NuMaSS project is on track to **perform** all the activities required of it by the SM CRSP Management Entity. In addition, the project has shown excellent performance with respect to leveraging USAID funding as identified among the project accomplishments. There has been exemplary performance with regard to mobilizing in-country science and technology and fostering capacity for innovation. In addition, performance directed to strengthen agricultural training and education, outreach and adaptive research has been very strong.

In a couple of exceptional cases, NuMaSS did not perform as expected indicating the need to refine the model or limit its use: "However, in the case of our validation trials, the software failed to detect nitrogen needs of the area which we attributed to very low phosphorus content of the soil."

The ultimate **impact** for the NuMaSS technology is effective and efficient soil-crop fertility management that will result in secure production in the realm of food, fiber, environmental protection and perhaps in the future, bio-energy, to name a few. Indicators of proximate impact relate to NuMaSS technology uptake pathways. As per the aforementioned examples, the NuMaSS project has changed the way the fertility management business is conducted in Thailand and the Philippines where NuMaSS has spawned supporting technologies. The supporting technologies have taken hold in Timor-Leste and several West African countries. In Central America and Angola, the NuMaSS project is directly responsible for reestablishment of functioning soil and plant testing laboratories that translate into commitments for more informed crop management practices. Examples of significant acreages of cropland in the Philippines and Thailand have increased yields and improved cropland productivity as a direct consequence of the NuMaSS project.

Clearly the NuMaSS project has made an **impact** on agricultural training and education, outreach and adaptive research. As a direct consequence of the NuMaSS networks, south-south interaction is mobilizing science and technology-based agriculture and environmental studies not only within, but also amongst countries in Southeast Asia and Africa and Latin America.

The potential for future **impact** on agricultural productivity and food security will be greatly affected by farmer circumstances, most notably the degree of agricultural market participation, which varies widely across and within potential collaborating countries. One conservative measure of market participation in the agricultural sector is commercial fertilizer consumption. In the decade from 1995 to 2005, NPK consumption in Latin America has gone from 9 million tonnes of nutrients in both regions to 17 million tons. These statistics suggest a growing demand for effective and efficient soil fertility management in Latin

America. While farmers in all regions are using fertilizers to some extent—be they subsistence or commercial operations—there are examples of misuse in all categories—be it under or over-use—and choice of inappropriate sources. NuMaSS is helping research/extension/fertilizer sectors provide recommendations that are site- and crop-specific, thus minimizing risk to all farmer categories.

During the same decade of growing demand for effective and efficient soil fertility management, however, public funding for agricultural research and particularly extension services in Latin America have been cut or eliminated all together. As the private sector research staff is forced to assume the role of a disappearing extension sector, it is not so much a case of fee-for-service as it is share-the-fees-for-service. As this change in responsibilities occurs, the resources available to the research staff do not increase. Researchers focus their efforts on local farmer organizations, like cooperatives, and NuMaSS helps them to convey the most appropriate nutrient management alternatives for soil- and crop-specific situations.

In Africa, forty countries recently agreed at a Fertilizer Summit to reduce taxes on cross-border flow of fertilizer. This would seem to indicate a policy to promote the use of fertilizer inputs.

Fertilizer nutrient consumption in Southeast Asia has been stable at 9-10 million tonnes over the past decade. The Thailand experience seems to indicate the market orientation and concomitant pressure for efficient and effective soil-crop fertility management is a driving trend to more precise "site-specific" crop management. Information from site-specific soil management reduces environmental pollution, lowers the cost of production and increases the efficiency of production. This was observed with maize production in Thailand. Site-specific agronomic technologies will also increase the demand for semi-skilled agricultural labor particularly if fertilizer-blending initiatives at the local level support it.

Another suggested socio-economic factor capable of creating potential opportunities for the growth of NuMaSS adoption, specifically, and software decision aids, generally, is the trend towards more formally-educated, "second-generation farm sons and daughters" from innovative farm families choosing to return to work the land.

There is evidence that NuMaSS technology, i.e., software-based decision support, is sustainable after the development project ends. USAID funded development of a precursor to NuMaSS, a decision support tool for managing acid soils, ended in 1996 but the National Agricultural Research Service of Panama is using the technology to this day. Special funding from USAID in Washington had been used to support soil science research networks in Latin America, providing researchers like Benjamin Name with exposure and training in Acid 4 DSS. Name put it into daily use for lime recommendations to farmers by the IDIAP lab he administered in Divisa, Panama. The NuMaSS lime component is based on the Acid 4 DSS precursor and Name feels comfortable, through prior experience, to continue using NuMaSS for lime recommendations in Panama. Successful application of these tools required two things from USAID, and both involve their commitment of funding: 1) support of Acid 4 DSS and NuMaSS development, and 2) support of U.S. university faculty to give technical backstopping support to interested overseas organizations who want to use and can benefit from using such tools.

Recommendations

Component research on rock phosphate and on the K algorithm could be emphasized in areas in Senegal and Mali. The component research for the rock phosphate will be the final year for a

Ph.D. study on the development and adaptation of the rock phosphate module for West Africa, and thus it is the completion of a three-year field study. The K algorithm work proposed for 2007 is the second year for field studies (financed by the Swedish Government) and may be the first year for expansion to Senegal. The Senegalese scientists are in agreement that the extreme K deficiency identified through the soil sampling for C needs an immediate resolution.

University led experience in site-specific soil management is one of a handful of success stories that have emerged in the second phase of the SM CRSP from 2002-2007. It offers one of the best and most challenging opportunities for ex-post impact assessment on the development consequences of the adaptation and application of soil-science related-knowledge. This opportunity needs to be fully exploited.

SM CRSP and NuMaSS project personnel are arguably the primary reason for the introduction of NuMaSS in collaborating countries. Less certain uptake of NuMaSS software has been through website downloads. It is recommended that the Project define potential uptake pathways for NuMaSS technologies under alternative scenarios, including, for example, an end-user "fee-for-service" scenario.

During the second phase of the SM CRSP from 2002-2007, significant resources have been allocated to software-based decision aids. This includes not only NuMaSS but also the Trade-off Analysis and Carbon Sequestration projects. It is recommended that a synthesis of relevant lessons learned be documented as to the strengths, weaknesses, opportunities and threats with respect to information and decision support technology compared to alternative, traditional methods.

Write up one or two success stories for USAID's *FrontLines*.

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

Principal Investigators: John M. Duxbury and Julie G. Lauren, Cornell University

Objectives

1. Develop methods to accelerate technology transfer of soil-management products and practices and to scale up technology adoption from local to national and regional scales.

2. Provide government agencies and policy makers with information to support development of programs and policies that encourage the adoption of soil management practices compatible with the long-term conservation of agricultural resources.

Accomplishments

1. Transferred Healthy Seedlings Technology (HST) to 15,000-18,000 farmers (48 percent women) to address pervasive soil/root health problems in rice and vegetable production in Bangladesh and Nepal.

2. Documented moderate (rice) to high (vegetables) adoption of HST, together with excellent productivity increases (10-40 percent for rice and 20-100 percent for vegetables), large economic benefits to households and the commercial sector (vegetable seedling sales, seed companies), and farmer application to high value crops (hybrids, flowers, spices).

3. Identified spatial patterns of root health problems for targeting areas most benefited by HST.

4. Enhanced the ability of technology transfer partners to deliver appropriate technologies to

households by linking to NARS, who provide training and technical backstopping.

5. Developed a model for technology transfer using existing infrastructure of farmer community groups (former USAID funded CARE FFS) with permanent beds as the example technology in a rice-wheat based cropping systems. Established positive productivity (+20 percent), improved natural resource management (reduced water use 30 percent) and economic impacts (up to 2x conventional practice) with farmer use of the technology.

6. Identified key factors that encourage or limit adoption/scaling up of soil management technologies.

7. Developed the capacity of Bangladesh scientists to predict lime requirements of acid soils in Bangladesh, produced national maps of lime requirements and documented yield responses of major crops to lime. This area will be extended to economic evaluation.

8. The component has been particularly effective at providing the poor with more options. According to one of the questionnaire respondents, "New economic opportunities have opened up for resource poor farmers (seedlings, flowers, vegetable produce) and service providers (plastic supply)."

Assessment

The overall assessment of the questionnaire respondents was that this component was effective because it contributed to better yields, it helped diversify household incomes, it developed affordable and appropriate technology and it partnered with very effective outreach partners. It was particularly effective in helping poorer farmers as it provided them with technologies that could be used on a range of crops and which were affordable. And, as one respondent noted, it is healthy to the natural resources base, "Environmentally sound technology-soil borne pathogens eradicated without applying external inputs, accessible to farmers and impact lasting more than one crop cycle."

The work in this adoption research phase (2002-2007) builds strongly on the component and systems research conducted in the first phase. The project centers on five technologies to increase the productivity of the rice-wheat cropping system that accounts for millions of hectares of cultivated area in South Asia. These technologies are: 1) the Healthy Seedling Technology (HST), based mainly on solarization, for the production of rice and vegetables, 2) raised permanent beds, 3) micronutrient rich seed of rice and wheat, 4) liming and 5) the surface seeding of wheat. Research on the surface seeding of wheat has concluded and results were reported in a final publication.[1] Technology transfer focuses on the Healthy Seedling Technology, which is an important success story for the project and for the SM CRSP as a whole.

The quality of research is very good with four journal articles published or submitted during the past year. Two graduate theses were also conducted. Adoption studies on the early acceptance of HST have identified constraints to early adoption and have pointed to directions for targeting technology transfer. Improving productivity in the rice-wheat cropping system is as relevant as ever since several hundred million people depend on this cropping system, which has been stereotyped by stagnating performance.

In contrast, performance in technology transfer of the Healthy Seedling Technology has

[1] Meisner, C.A., I. Hossain, A.S.M. Talukder, A. Sufian, J.M. Duxbury, and J.G. Lauren. 2002. Changing tillage paradigm in South Asia: Wheat sown on beds. *In* American Society of Agronomy Abstracts: 10-14 Nov 2002, Indianapolis, IN.

been more than adequate with thousands of households exposed to solarization techniques featuring multiple partners using an array of methods for technology transfer. Although not yet well documented, the field-level value of the Healthy Seedling Technology will almost certainly exceed several millions of dollars annually if diffusion continues as expected. Poor rural women are a primary beneficiary group for this technology.

The effects of solarization on seedling vigor have been well documented and adoption of the technology is proceeding apace. Individual beneficiaries, such as Mrs. Anwara, have gained much from selling high quality seedlings. Most encouraging was the evidence of farmer experimentation with the solarization of soil placed in plastic bags to grow vigorous cucumber vine seedlings for sale. At another level, the private sector involvement in vegetable seedling production and sale is an encouraging development. The benefits include lower seed costs, a better product and stronger seedlings.

The HST is for all farmers but it is especially relevant for small farmers. The premise of the solarization technology is to address pervasive soil/root health problems as illustrated through the extensive mapping which shows the extent of the root knot nematode in Nepal, Bangladesh and Thailand. Training has for the most part concentrated on NGO clients, who are mostly marginal, or poor farmers and in many cases women. The project's 2004-05 Annual Report emphasized that increased rice production from Healthy Seedlings was not a motivating factor for medium to large sized farmers where food security was not a concern, but it was for food insecure families for whom producing more rice was an important and motivating factor. A major advantage of HST is that it applies to a wide variety of crops and situations, from poor farmers to seed companies and commercial vegetable and flower sectors. It also has multiple outcomes in that HST application to vegetables addresses human nutrient deficiencies as well as income generation.

The key to the use of permanent beds is the availability of the bed-forming tillage equipment and tractors. Entrepreneurs in the Alipur community, working with the NGO CARE and BARI scientists, undertook participatory field trials to assess the permanent bed system. The benefits of raised beds are less labor, easier weeding, savings in seed, water and fertilizer, fewer rats and heavier yields. Potential disadvantages, apart from higher tillage costs (capital), include a greater threat of herbicide damage.

Finally, the focus on outreach has been particularly effective. As noted by a respondent, "The program has been effective at raising the awareness of thousands of farm households about Healthy Seedlings through partnerships with NGOs having relatively large coverage (CARE, RDRS)."

Recommendations

2006-2007

The success story of the Healthy Seedling Technology needs to be documented via a formal economic impact assessment. The project contains many of the ingredients for such a benefit-cost study. A point-estimate of adoption for the most recent year needs to be generated, the recommendation domain should be defined and the net benefits per hectare of HST requires calculation over the user groups of rice and vegetable growers in the sandier soil regions where nematodes are more problematic.

The adoption experience with the Healthy Seedling Technology and other SM CRSP technologies needs to be synthesized, and one or both of the principal investigators of this project are in an ideal position to lead this effort. The synthesis should examine partners,

technology transfer methods and paradigms and characteristics of the technologies.

Writing up one or two human-interest stories for USAID *FrontLines* on the adoption and impact of HST is highly complementary to the economic impact assessment and the synthesis of the adoption experience.

Although the project is not taking on any more new partners, the demand for HST technology transfer should be met in new areas, such as vegetable seed production in peri-urban, sandy soil tracts, where prospects are the brightest for cost-effective transfer with the "old" partners. The adoption studies to date show that the various technology transfer processes used by NGO partners have generally been successful. However, the sustainability of the different approaches is a major question. The FFS model is unlikely to be sustainable without continuing institutional support and this cannot be provided by International NGOs because they operate on a project basis. Candidate "institutions" for this task would be the national extension system or large national NGOs whose presence is stable over time. However, the national extension systems do not use the FFS model, nor do they have the financial resources to step into this role. So, ultimately we will suggest that donor agencies change either whom they fund or that they introduce requirements for sustainability at the country scale.

Ways need to be found to enhance the availability of quality plastic in Nepal. Input suppliers could perhaps be more involved in the transfer of the technology. At a minimum, quality plastic could be made available at cost to prospective adopters to gauge the size of the quality-plastic constraint in the rejection or poor performance of the technology.

The Principal Investigators (PIs) have done a good job in getting farmers involved in the raised bed technology. Farmers are likely to play a major role in shaping this complex technology. Exposure to the permanent bed technology is to be encouraged, not for diffusion per se, but to attain a critical mass of farmers to work with to address and update component research issues that are alluded to in the project's 2005-06 Annual Report.

With raised beds, more work is needed to understand the consequences to the nitrification/ denitrification dynamics and N availability to the crops resulting from a shift in the spatial and temporal dynamics of aerobic/anaerobic soil zones due to the drastic change in water regime brought about by the land shaping.

2008-2009

A small amount of money is required to support a backstopping position for technology transfer to ensure that the diffusion of the Healthy Seedling Technology is not compromised. Failure to make this small investment could result in thousands of poor households not having the opportunity to benefit from this technology.

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

Principal Investigators: John Antle, Montana State University and Jetse Stoorvogel, Wageningen Agricultural University

Tradeoff Analysis (TOA) is a process designed to link public stakeholders and policy makers to teams of scientists with tools that can provide information and knowledge that is useful in understanding complex problems. The TOA approach and tools are unique in that they represent the first time analytical tools have been coupled with a participatory approach that links them to the stakeholders and policy decision makers through scientific teams at local

institutions. The development of the Minimum Data (MD) approach is a unique contribution that greatly enhancing the usefulness of the approach, by reducing the amount of data and training required for the tools to be useful to users. Other alternative modeling approaches are highly data-intensive and require extensive training. CIP, the Panamanian agricultural research institute, and FutureWater, both of which have been attracted by this feature of the TOA approach, are adopting the simpler MD approach.

TOA allows scientific teams to quantify and visualize tradeoff relationships between key sustainability indicators under alternative scenarios designed to represent changes in policy, technology and environmental conditions that are of interest to policy decision makers and other stakeholders. TOA also allows decision makers to more effectively compare costs and benefits of various options, including policies, technologies, environmental conditions, etc. Policy makers, once trained, also use the TOA directly to compare costs and benefits of various options. TOA also provides a systematic approach to design and implement multi-disciplinary research projects. The project is continuing to develop and refine the TOA model software through applications with collaborating institutions in the Andes, West and East Africa.

Objectives

1. Further develop and refine the existing TOA and TOA model software through applications with collaborating institutions in the Andes, West Africa and East Africa.

2. Develop methods to scale-up the analysis possible with the TOA method from single agro-ecozones to larger regional scales.

3. Development of protocols and materials to transfer the TOA method and the TOA model software to existing and future user groups.

Accomplishments

The TOA approach is recognized internationally for its role in leading the development of impact assessment technology that involves science based information and management decision/ policy makers in complex issues. It is being used by a number of countries, technology development and transfer is going forward and the approach appears to have global applicability because it is based on fundamental, natural processes that transcend political boundaries. This project is fully integrated with the carbon sequestration project and has formed alliances with other universities and in-country partners.

A significant limitation to widespread application of spatially explicit simulation tools is the need for a large amount of data. A notable accomplishment is the development and testing of 'Minimum Data' (MD) methods to parameterize the economic models used in TOA.

Specific outputs include the development of the *Tradeoff Analysis Software User Guide* and the TOA on-line training course, prepared for the Dakar and Nairobi workshops.

Other significant accomplishments have been development of the interfaces between the TOA software and environmental process models (the WEPP erosion model, the LEACHP chemical leaching model, Stoorvogel's tillage erosion model, the NUTMON nutrient balance model, the DSSAT/CENTURY crop and soil carbon model) and procedures for linking the Nutrient Monitoring databases to TOA. Significant progress has been made during this phase of the project in developing collaborations with national and international institutions that will use the TOA methods and software. As one

respondent noted, "TOA methodology compels experts in different fields to work together."

At present partners include the following institutions:

- Consortium for Soil Mitigation of Greenhouse Gases (USA)
- Ecole National de Economie Applique (ENEA, Senegal)
- International Potato Center (CIP, Lima and Nairobi)
- Institut Senegalais de Recherche Agricole (ISRA, Senegal)
- Instituto de Investigacion Agropecuaria de Panama (IDIAP, Panama)
- Kenya Agricultural Research Institute (KARI, Kenya)
- Makerere University (UA, Uganda)
- Montana State University (MSU, USA)
- Peanut CRSP (University of Connecticut)
- Savanna Agricultural Research Institute (SARI, Ghana)
- Wageningen University and Research Center (WUR, Netherlands including Institute of Agricultural Economics (LEI))
- World Agroforestry Center (ICRAF, Kenya)
- FAO

Assessment

Progress towards individual project objectives is excellent and continues to be relevant. Adherence to the annual work plan and milestones is good and supports the project objectives. Scientists have shown creativity and innovativeness in improving TOA. The TOA project allows for biophysical information and knowledge to be used by management decision/ policy makers and other stakeholders in addressing important social-economic problems such as the carbon sequestration/carbon trading issue and the Carchi Province, Ecuador pesticide human health issue. The information, knowledge and technology being developed by this project is providing the necessary decision support tools to link public stakeholders and management decision/policy makers to teams of scientists that can provide information and knowledge that is useful in understanding complex problems and evaluate the tradeoffs. TOA also provides a systematic approach to design and implement multi-disciplinary research projects. Some examples are: 1) CIP is building a TOA team to implement a project on biodiversity protection in the Altiplano region, 2) the Panamanian agricultural research institute has adopted TOA to implement its project on water quality in the canal zone, 3) the ARS Northern Great Plains Research Laboratory in Mandan plans to use TOA in establishing a new center on agroecosystem research and 4) FutureWater, an NGO, is using TOA to compare incentives for water quality protection in Tibet. Quality of research, model development and transfer activities are well documented in quality-refereed journals. For example, the American Journal of Agricultural Economics, Agricultural Economics: An International Journal, Agricultural Systems, Soil Science Society of American Journal, the Journal of Environmental Management, book chapters, symposium proceedings and training materials. The TOA approach is recognized internationally and it is also appreciated locally. As one respondent commented, "The science in the project is state-of-the art. This is demonstrated by the publications and demand for training."

Performance by the individual scientists involved in this project is excellent as demonstrated by the number of publications, training workshops, development of new technology and number of problems being analyzed.

The greatest **impact** of this project so far has been the pesticide use and human health issues addressed in Carchi Province, Ecuador. The TOA project outcome changed pesticide application and handling practices, resulted in a declaration on pesticide regulation, a BBC

radio program on pesticide problem in Carchi and an IDRC grant to CIP to scale-up pesticide analysis (2003-2006).

The International Potato Center has adopted TOA as the basis for analyzing natural resource management programs in East Africa and analysis of resource management options in the Altiplano region of Peru. TOA has been used successfully to analyze the impacts of climate change in Peru and carbon sequestration in Peru, Ghana, Senegal, Kenya and Uganda.

TOA graduate and in-country training/capacity building has established a solid base for significant impact. Some examples of capacity building follow.

- Ecuador—IDRC funded farmer field schools and community education and training of INIAP students.
- Peru—training of PRONAMACH staff and university students.
- Ghana—training of SARI staff and UG faculty.
- Senegal—training of ISRA staff, and ENEA faculty.
- Kenya—training of KARI, ICRAF, CIP staff, and livestock CRSP Collaborators.
- Uganda—training of MU faculty and students, TOA used in regional Master's degree program, TOA used in International Association of Agricultural Economists Learning Workshop.
- Panama—training of IDIAP staff.
- United States and the Netherlands—LEI staff trained in use of TOA, graduate course based on TOA offered spring 2006 at UC Davis.

Nevertheless, some saw a need to further refine the tool, "Although a large number of people have been trained, some of the tools require further simplification to be widely used by policy advisors."

Recommendations

- Place the reporting emphasis on outcomes (impacts) and significant research output rather than on meeting internal funds/ administrative accountability.

2006-2007

- Focus on completing project and developing significant scientific output and impacts made by the project.

- Continue to develop and improve the TOA training course materials.

- Use TOA analysis to evaluate payments for environmental services as a new approach to tackle land degradation in Pallisa District, Uganda.

2007-2008

- Pilot test the carbon methodology to evaluate incentives and transactions costs in a real-world setting.

- Support Kenya Agricultural Research Institute's continued use of TOA for research and policy analysis.

- Encourage Institute of Agricultural Economics, Netherlands to use TOA to assess feasibility of additional NUTMON applications.

- Utilize the set of Nutrient Monitoring case studies in Kenya, Ethiopia and Uganda to develop TOA applications and scale-up these studies to the regional level.

- Synthesize the comparative experience from TOA results on land degradation across the Phase 1 and Phase 2 study locations.

Measurement and Assessment of Soil Carbon Sequestration by Agricultural Systems in Developing Countries

Principal Investigators: (1) James W. Jones, University of Florida; (2) Russell Yost, University of Hawaii; (3) John M. Duxbury and Julie G. Lauren, Cornell University

Carbon in soil plays a key role in soils as a reserve of essential nutrients, a source of cation exchange capacity and a binding agent in soil aggregation. For acid, highly weathered tropical soils, carbon plays a central and essential role in soil productivity. In addition, tropical soils provide a large potential sink to capture and store carbon. Greater use of this sink could help counter the rising atmospheric CO_2 concentration while reducing soil degradation and improving crop productivity in many areas of the world.

While crop productivity is the current and immediate dividend from increased soil carbon, there are real opportunities for farmers in developing countries to receive payment for storing carbon in their soils. However 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 for carbon storage are being met. Because measurement of soil carbon changes over the large areas needed to sequester contract amounts of carbon is not possible, other approaches are necessary.

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 challenged in soil organic matter (SOM), but where technologies exist to rebuild SOM. The major driver of soil degradation in West Africa is poor utilization of available resources, while in South Asia it is deliberate destruction of soil aggregates by puddling for rice.

The project 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. Specifics differ as to the constraints and opportunities in each region.

Objectives

1. Develop practical methods to measure gains and losses of soil organic C over time in spatially variable soils.

2. Apply methods to assess the potential for carbon sequestration for selected sites in West Africa and South Asia.

Accomplishments

West Africa

1. Mali, Senegal, The Gambia

- A new technology, ridge tillage (ACN), developed by CIRAD, has been characterized and documented by IER and SM CRSP scientists to provide multiple benefits for producers in West Africa. Benefits include:
  - Reduced runoff, downstream flooding and sediment-related damage.
  - Crop yields are increased 30 to 50 percent.
  - Crop yields are stabilized, especially in dry years.
  - Increased water availability for shrubs and trees—including trees providing cash earning opportunities (shea butter).
  - Increased deep drainage that replenishes groundwater supplies, and, in some cases, provides opportunities for vegetable garden irrigation in the off-season. (Deep drainage was estimated by the use of a set of 24 probes that measured water content at 10 cm depth increments every other day for two rainy seasons.) The results

indicated a 94 percent reduction in rainfall runoff and a 132 percent increase in deep drainage (defined as the cumulative amount of water flowing from 70 to 90 cm depths over the duration of the rainy season).
    - Increased soil organic C, which in these impoverished, highly weathered soils leads to increased nutrient content, nutrient retention capacity, improved water retention and improved water infiltration.

- New options for household income and diet diversification are possible including the option of producing vegetables in the off-season. (A village survey conducted in early 2006 indicated that the original village where ACN was developed now has an acceptance rate for ACN of about 90 percent. A local NGO has assisted village households to dig hand-dug wells that now provide water for off-season irrigation, a heretofore unheard of practice and one which never existed according to local knowledge before the ACN was introduced. The popularity of this household income source and diet diversification practice is indicated by 80 percent of village households that now have vegetable gardens managed by village women.)

- Malian, Senegalese and Gambian scientists are learning improved site-specific nutrient management techniques, use of decision-aids, how computer-based tools can enhance performance and achievement of their institutional mission.

- The ACN provides new options for the mitigation of climate-change induced drought, loss of productive capacity and helps improve food availability and security. In the larger context, ACN is one of the few soil and water conservation (SWC) measures at the disposal of farmers on deep, sandy soils—which cover much of the Sahel. (Another is Farmer-Managed Natural Regeneration (FMNR), which is more of a complementary *vs.* competitive technology.) Farmers have treated hundreds of thousands of hectares of hard pan soils with contour berms, demi-lunes and zais in Mali, Burkina and Niger, but FMNR is only seen on deep, sandy soils.

- Farmers in Senegal have adapted the ACN technology for peanut production systems, where peanut is planted without ridges and then ridges are subsequently put in.

- A survey of Southern Senegal indicates that soil K is extremely limiting and a source of fertilizer K is needed to immediately restore this widespread deficiency.

- Senegalese farmers, especially affected by low rainfall in the central part of the country, have new options for mitigating the devastating effects of drought induced by climate change.

- On farms adopting ACN in the Gambia, levels of soil organic C were nearly doubled– a very significant increase in these impoverished soils. The ACN has been heartily received by the farmers of The Gambia; with only three years of introduction, over 200 farmers have now adopted ACN in The Gambia.

2. Ghana

- Quantified the vulnerability of soils in Ghana where poor management and continuous cropping for three years caused soil organic matter loss to a point where the soil is barren; now assessing the degraded soil recovery time through in situ plant growth. Because of the major differences in soil degradation among the treatments, an outreach effort is planned to demonstrate the consequences of poor soil management on productivity and on soil carbon to the farmers in this region. In addition, the project is initiating a new effort to characterize the effects of degradation and the practices for increasing soil carbon on biodiversity of soil organisms,

in cooperation with the biotechnology SM CRSP effort. An effort will be made to inform the government of Ghana of these findings to emphasize the importance of promoting management practices that retain or increase soil carbon in this region.

- Demonstrated management practices in a maize cropping system that maintain soil carbon levels and maize productivity following native fallow using different managed fallows (pigeon pea, mucuna, cowpea and native bush grasses). Intensified maize production using fertilizer and no-till significantly increased yield and soil carbon above native fallow levels.

- Developed new technology for monitoring changes in soil carbon levels over time and space by combining soil sampling with models to provide estimates of aggregate soil C tonnage along with an estimate of the reliability (or uncertainty), enabling the design of cheaper sampling/monitoring schemes at target levels of uncertainty.

- Developed tools for predicting crop production and changes in soil carbon in West African soils and climates, by adapting models that integrate soil, weather and crop responses to the harsh prevailing environments. This was to support new policies on food security and environmental services, while enabling the assessment of the potential for soil C sequestration levels over large areas.

- Demonstrated how to link biophysical and economic models developed in the TOA to assess potential adoption of management practices and potential impacts on food security and soil carbon levels. The TOA project in SM CRSP is already making use of these linkages in their training programs and research in other regions. There is a high chance that the State of Florida will make use of this in their research on best management practices and environmental services. This latter adoption demonstrates the value of USAID funds in domestic programs as well as international efforts.

- Adoption of models by eleven national and international research and development institutions, such as CGIAR Centers, the African Network of Soil Scientists (AfNet), IFDC and others. This adoption by others is an important indicator of the relevance of the models.

- The approach developed provides a basis for a "*Research for Development*" paradigm that can be transferred and adopted for specific development goals.

- Training and Capacity Building. Ten graduate students are being trained on the UF-Soil Carbon project, four in Ghana, two in Mali and four in Florida; training workshops held in Ghana and Mali on integration of Decision Support Tools (DST) and on-farm research into research programs and understanding minimum data needs; and the use of both biophysical and economic models to scale up research results and understand the effects of policies on adoption of new technologies.

3. South Asia

- Improved the capacity of NARS laboratories to measure soil carbon and texture parameters with the precision and accuracy needed for them to contribute to potential carbon trading opportunities.

- Estimated maximum potential carbon sequestration for South Asian soils in the rice-wheat cropping system, using soil carbon-texture algorithms developed for cultivated and native soils.

- Quantified soil organic carbon gains under specific nutrient, reduced tillage and residue

management practices in the rice-wheat cropping system.

- Applied GIS methodology to determine spatial patterns and soil C sequestration potential at the district scale (10s of kilometers).

- Developed reduced tillage practices suitable for both small and large farmers to increase soil organic C content.

Assessment

Mali, Senegal and the Gambia

Carbon sequestration in agriculture systems, *amenagements en courbes de niveau* (ridge till on contour) [ACN], is the central concept of the University of Hawaii's component. It addresses social and economical aspects, assesses soil water properties, ground water recharge, changes in soil carbon and the number and productivity of trees. The project is focused on the enhancement of soil productivity with an emphasis on management of soil fertility and soil water. The **relevance** of the information, knowledge and technology being developed by this project lies in its potential significantly to increase food production, improve the natural resource base, and enhance economic and social conditions of smallholder farmers over millions of hectares in Sub-Saharan Africa. The high **quality** of the research on ACN technology as it is being adapted to Sub-Saharan Africa conditions is demonstrated by the quality field experiments and the results published in refereed journals. However, the impact of ACN technology on village social/economic conditions has yet to be documented by research and reported in refereed journals. The teamwork, collaborative research environment and systems approach is excellent and sets the SM CRSP and this project apart from other research projects in the region.

Good progress towards individual project objectives and adherence to the annual work plan and milestones is evidence of outstanding **performance**, but adoption will be enhanced by a greater involvement of NGOs. Scientists have shown creativity and innovation in their work to implement ridge till under contour to Sub-Saharan Africa conditions and conduct quality research that documents its impact on farm productivity. Examples are conservation of natural resources (i.e., soil, carbon, water and nutrients and plant bio-mass); community diversification, e.g., empowerment, decentralization, improved health and economic status; and empowerment of NGOs.

The potential **impact** of the ridge tillage (ACN) technology developed in Mali and applied in several Sub-Saharan Africa countries is illustrated by positive outcomes such as: 1) runoff reduced by 20 to 40 percent; 2) soil water content increased 10 to 30 percent; 3) deep water percolation increased; 4) increased biodiversity and shea butter trees fruit production; 4) and increased soil organic carbon from 0.2 to 0.4 percent. Revised recent data from two years indicate that rainfall runoff can be reduced by 94 percent and deep percolation increased by 135 percent. (Rainfall runoff reduction and deep drainage was estimated by the use of a set of 24 probes that measured water content at 10 cm depth increments to a depth of 160 cm every other day for two rainy seasons.) These water content data were summarized in a field water balance that measured soil water content, measured rainfall, calculated evapotranspiration and calculated runoff and deep percolation. (Over 25,000 individual water content measurements were used for this summary.) Consequently, land that had gone out of production is being reclaimed; land productivity and rural incomes increased; tree fruit production and availability of well water to irrigate vegetable gardens and for house hold use has increased; crop yields are stabilized (especially in dry years) and have been increased 30 to 50 percent; and soil erosion by rainfall is reduced.

An example of the **impact** of adoption of ACN is the case of Drissa Traoré, Fansirakouro, Mali. Drissa's farm was chosen because it was near the village and he had little land. The land was steep and the rainfall amount, while significant, was never enough to grow other than sorghum in wet years and millet in dry ones. With the first year of ACN, he had more water than expected for the sorghum. The second year he planted maize, which yields more and has greater market value, and his attempt was rewarded with a good crop. He continued to grow maize, some of which he could sell. He amassed some funds and in a few years he was able to purchase his first set of bullocks, plow and cart. Previously he did not have a complete set of bullocks, plow and cart and was classified (by IER) as a Class D farmer. With his new purchase, he moved from a Class D to a Class A farmer (one with a complete set of bullocks, plow and cart). Drissa now has expanded his crop choice to include the cash crop cotton in rotation with maize, and he is considering other cash crops. In addition to time and money, there are the social, economical and personal constraints of dealing with change and how to effectively transfer this technology to Sub-Saharan Africa. The close interaction between the Tradeoff Analysis (TOA) project and the Carbon Sequestration project provides a positive framework to deal with social and economical constants related to adopting ACN and carbon sequestration technologies.

The scientific community has accepted the ACN technology as an excellent tool to manage water and soil resources. The research findings are extremely promising on the potential for ACN technology development and adoption over large areas in Sub-Saharan Africa is excellent.

Ghana

The University of Florida component of the SM CRSP is focused on 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. The project is also assessing the potential for different management practices for sequestering carbon in West Africa soils.

The **relevance** of the information, knowledge and technology being developed by this project is high with regard to the provision of tools necessary to determine the mass of soil carbon stored under different land management practices and provide the necessary temporal and special variability information to assure carbon traders that contract levels are being achieved and maintained. In addition, increases in soil organic carbon has the potential to significantly increase food production, improve the natural resource base and enhance economic and social conditions of smallholder farmers in Sub-Saharan Africa.

Research and technology development is of high scientific **quality** and is being well documented by field experiments, model validation and testing. Research findings are actively being published in quality refereed journals. The improvements made to the DSSAT model and its linkage to the CENTURY model has been a quality effort. The DSSAT model is recognized by the research community as an excellent decision support tool, especially for use in the Tropics. The adoption of the Kalman Filter technology for use in agricultural systems is another example of advanced and innovative high quality research. For example, the DSSAT-CENTURY model is being used by researchers across Africa through an effort by AfNet, the African network of soil fertility researchers, to help them develop more sustainable soil management practices related to soil organic matter and soil fertility. The Kalman Filter represents a major new development in natural resources management. (Interest exists in the US in adapting it for soil carbon estimation and for soil water monitoring for drought early warning.)

Performance in terms of progress towards individual project objective and adherence to the annual work plan and milestones is good and supports the overall project objectives. Scientists have shown creativity and innovativeness in improving decision support technology to assess soil carbon sequestration by Agricultural Systems in Sub-Saharan Africa. The cooperative work with the TOA project allows for biophysical knowledge to be used in addressing important social-economic problems such as the carbon sequestration issue.

The high **impact**, both achieved and potential, is reflected in the adoption of the new tools by other programs. These include the International Research Institute for Climate and Society (IRI) that uses the DSSAT in India and in Africa to study the impacts of climate variability and management options to make use of climate information and forecasts for reducing production and food security risks, and the African Network for Soil Fertility (AfNet), CIAT/TSBF and ICRISAT which have each adopted the DSSAT to improve their soil fertility management research. The other main impacts have been on capacity building, development of datasets that are used to compare soil management practices across locations and on cropping systems. Over 80 researchers in Africa have been trained in the use of DSSAT, based on leveraged funds. Of these 80 trainees, about 30 continue to use DSSAT in their soil management research and are asking for more advanced training, which is being planned by the African Network for Soil Fertility researchers. AfNet leaders are interested in adopting the TOA model. IFDC has been helping refine the DSSAT model and promote its use in West Africa. IFDC-Togo is helping support a MS degree student to build capacity to adapt the model for use in West Africa. Applications of the refined DSSAT Model include the following:

- The Southeastern Climate Consortium, with participating universities in Florida, Alabama and Georgia are using the DSSAT models to support the Cooperative Extension Services work on agricultural production risks options.

- The Ensemble Kalman Filter used in the project has been adopted by ICRISAT to use with remote sensing to estimate production variability over large areas.

- The Florida Department of Agriculture and Consumer Affairs has adopted DSSAT for use in advising farmers on reducing nitrate and phosphorus pollution in lakes and streams.

- The Florida Departments of Agriculture and Environmental Protection have also agreed to use of the Tradeoff Off Analysis to help farmers to adopt best management practices.

South Asia

In the rice-wheat soils of South Asia, 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. Therefore, the research of the Cornell University group on the sustainability of soil productivity in the rice-wheat systems of the Indo-Gangetic plain is highly **relevant** to the food security of the hundreds of millions of poor who depend on these areas for supplies of staple food grains. The focus on the assessment of the effects of tillage and residue management on carbon stocks, the soil-carbon relationships and C measurement issues, complements the technology adoption studies covered in the section on the rice-wheat system. The high **quality** and rigor of the studies on laboratory methods for measuring soil carbon provide

valuable guidance to collaborators in Nepal and Bangladesh. The quality is determined by using standard reference materials and through inter-laboratory comparisons between NARS labs and Cornell.

The same is true of the use of models and field data from long-term experiments in Nepal to analyze past trends and future carbon levels subject to different tillage and crop residue treatments. The work has led to several reports and presentations.

The **performance** towards project objectives has been influenced adversely by low capacity of the collaborators in Nepal and Bangladesh to undertake high quality soil analyses. These constraints, which are commonly beyond the control of the scientists, include poor facilities, interruptions in power supplies, institutional changes and lack of supervision of technicians. Nevertheless, the approach of combining measurements with models and the established relationship between texture and soil carbon levels will help predictions of carbon levels. The high soil heterogeneity and the tiny size of farmers' fields in the region, though, will frustrate attempts to scale up data collected on individual farms. Furthermore, little progress appears to have been made in research to understand the role of organic carbon in soil aggregation in relation to tillage treatments.

The main impact of the work so far lies with the training of scientists from the region and the conceptual developments of the texture relationships and modeling approaches. Training included one Ph.D. student from Nepal in Cornell and seven Masters students at Tribhuvan University. The training, in country, in cooperation with Tribhuvan University is an important feature since both the local university and the student benefit. An important advantage of this approach to capacity building is that students are most likely to remain and be usefully employed in their own country after graduation. A major potential impact is that with the adoption of the improved tillage and soil management technologies, such as the permanent bed system, the rate of soil carbon loss in rice-wheat systems will decline or even be reversed and this will mean a substantial increase in productivity.

Contributing to the above impact has been the quality of collaborative research. As noted, "The quality of collaborative research with NARS and various NGO groups has been very good. All are committed to their programs and work hard." Upper-level management has been very cooperative and encouraging. Ideas for program activities and discussions about results are free flowing between international and national partners. Despite impediments such as the Maoist insurgency in Nepal or nationwide strikes in Bangladesh, the national collaborators are very motivated to continue and find ways to work around or adjust to these troubles.

Recommendations

2006-2007

- Prepare vignettes for USAID on important advances such as the ACN (including topics such as: water conservation impacts, the role of soil carbon as a first step in intensification, the benefits of increased tree biomass in the carbon budget, etc.)

- PIs should collaborate to review and reconcile the different approaches to soil C measurement and modeling at different scales through sample exchange and the preparation of a global report reviewing the results in the different regions. In this regard the trade-off analysis could serve as a cross linkage.

2007-2009

- Complete the three graduate programs with the University of Hawaii that are in progress (1 to 1.5 years required).

- Increase technology transfer of ACN through collaboration with NGO and Extension Service to establish this technology as a very effective technique to restore productivity to millions of hectors of non-productive agriculture lands.

Biotech Project #A: Genetic Characterization of Adaptive Root Traits in the Common Bean, *Phaseolus vulgaris*

Principal Investigators: C. Eduardo Vallejos, Melanie Correll, James W. Jones, University of Florida

Objectives

The project's goal is to identify plant genes that control root traits and how these genes can be used to advantage with cultural practices in problem soils of developing countries. The work is addressed through four objectives:

1. To establish magnetic resonance imaging (MRI) as a reliable non-destructive procedure to measure root growth and to characterize root morphology in the common bean, *Phaseolus vulgaris*.

2. To survey *Phaseolus vulgaris* accessions from Andean and Mesoamerican origin, and assess the extent of genetic variation in root morphology, size and growth rate.

3. To identify and map, via Quantitative Trait Loci (QTL) analysis with molecular markers, genes that control root characteristics in the common bean.

4. To add the genetic information to the existing Crop-Soil model to predict the impact of using genetically improved cultivars in specific soil environments.

Accomplishments

The project has accomplished the following:

- Identified a low Fe background mineral soil suitable for both plant development and magnetic resonance images (MRI) of intact roots.

- Developed a reliable MRI protocol to visualize intact roots in soil so that their architecture in soil could be visualized.

- Detected polymorphisms among bean genotypes for root growth rates and architecture.

- Converted Restriction Fragment Length Polymorphisms (RFLPs) to Polymerase Chain Reaction (PCR)-based molecular markers in beans.

- Developed and successfully tested a 2-D chamber for more rapid screening of the 76 previously developed inbred lines.

- Used data from the 76 genotypes grown in Puerto Rico in the Crop Simulation Model to simulate root weight and density with depth and time.

Assessment

The project has an important biotechnology—soil management relevance, namely to understand how genetic traits controlling root development can be used to overcome soil barriers to productivity by exploring more and different soil volume for water, nutrients and minimize effects of pH and pests. MRI technology was proposed as a means to visualize root architecture in soil. The first challenge faced was to find a soil sufficiently low in iron so that the MRI image of roots could be distinguished. This was achieved, and the 3-D root image on a two-week old plant was as expected. The MRI technology is both

time-consuming and expensive in user fees, which has limited progress. Furthermore the image needs to be digitized for quantitative analysis, which remains a barrier to progress. Initial work has been done in collaboration with an image analysis expert, but much is left to achieve before the technology use can be realized and evaluated. While the proof of concept has been achieved for the MRI root imaging, considerable analysis, financial and throughput barriers exist before the original objective can be met.

An important opportunity to adjust the project occurred when the University hired Melanie Correll last fall. She brings experience in both 2-D root analysis and modeling, Hence, the project has been adjusted to use the 2-D system to more rapidly screen the 76 genotypes and, on a limited set, validate or calibrate the 2-D results *vs*. the 3-D results. The current work on the 2-D system has progressed rapidly giving promise of meeting a key objective by the project's end. Furthermore, through this augmented effort, available Puerto Rican field data on the genotypes in the crop growth model have begun to be used to simulate root development.

The **relevance** of the objectives to USAID goals is very high because *P. vulgaris* beans represent the major source of protein for over half a billion people in Africa and Latin America. These two regions are responsible for three quarters of world bean production. Depleted soils (nutrients and organic matter) and limited water availability have been identified as major constraints to bean production in these regions, in particular in subsistence agriculture. These constraints, however, can be overcome through the identification of genes that control adaptive root traits—root architecture that increases the efficiency of phosphorus acquisition, or water uptake. Incorporation of these traits into new cultivars can lead to increased productivity in marginal lands, and also become part of a soil management strategy for the revitalization of depleted soils. The work is illustrative of one of areas in which biotechnology can make an important advances for major soil management challenges in the highly weathered, impoverished soils of the tropical world. The **quality** of the work done so far is good, the team talented and the MRI facilities and staff among the world's best, but the extent of the accomplishments (i.e., **performance)**, is limited. No work has yet been published and no genotypes identified that have root architecture that would have improved productivity potential. The **impact** remains to be determined after the last phase of the work is completed. Unique resources, however, are in place that offer potential for substantial progress, namely 76 genotypes with molecular markers identified, reciprocal grafting technology developed, 2-D and 3-D systems for visualizing root images developed, and field data on the 76 genotypes over two years available for the crop (root) growth modeling.

Recommendations

Considerable work remains to be done, so it will be wise to prioritize efforts to obtain key results. In particular, since the 2-D work is less problematic, it should proceed as the highest priority to identify genotypes with major differences in root architecture, and use the MRI approach to be more confirmatory or backup technology, as well as exploratory, as time and funds permit.

2006-07

1. Evaluate all 76 RI lines with 2-D model for early root establishment, growth rates, density, and seed size and growth habit effects. Identify RI lines with root characteristics at extremes of distribution for the MRI 3-D analysis.

2. Develop image processing, i.e., digitize root images and the development of probability function (volume, density and branching).

3. Compare 2-D *vs.* 3-D root models for parental lines Jamapa and Calima and recombinant inbred lines from cross [Jamapa x Calima]. This should be limited to about six lines that represent the extremes and include determinate and indeterminate habits.

4. QTL analysis of root traits with molecular markers (350 marker loci already identified).

5. Computer simulation of root growth and density of RI lines field grown in Puerto Rico by J. Beavers and evaluation of relationships between simulation results and 2-D/3-D root data.

If the above work is able to identify genetic markers linked to root growth and architecture traits that are likely to address important barriers to bean productivity in problem tropical soils, this critical advance should not be lost. That is, work should proceed to develop and test new varieties in problem tropical soils in the 2007-09 time frame.

Note also that application of the techniques developed in this SM CRSP project to study root growth can readily be applied to other important crop species. In addition, the discovery of synteny (shared gene order) among related species raises the possibility for the discovery of similar genes in related legumes (soybeans, cowpea, alfalfa, etc.).

2007-09—Bridging Period

1. Calculation of genetic root-associated genetic coefficients for the Crop Model.

2. Design of cultivars with root characters suited for specific soil characteristics, especially those that address water and nutrient constraints and management practices.

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

Principal Investigators: Medha Devare, Janice Thies, John Duxbury, Leslie Allee, John Losey, Cornell University; Edmundo Barrios, Centro Internacional de Agricultura Tropical; Weixiang Wu, Zhejiang University

Objectives

The overall goal was to determine whether there were any ecological effects of the Bt gene in three crops. Field trials with Bt corn (NY), rice (China) and cotton (Colombia) were conducted over the past three growing seasons for corn and rice and for two growing seasons for cotton. All trials included a non-Bt isoline for comparison, along with the non-Bt isoline treated with insecticide (normal agricultural practice and rates). In NY, there was an added variable of field history (continuous corn history *vs.* alfalfa), which creates treatments with and without existing root worm pressure in the field. Main advantages of their experimental design are the inclusion of: (i) both lepidopteran (Cry1) and coleopteran (Cry3) protein coding constructs; (ii) three different crop species; (iii) and in two different cropping systems—predominantly aerobic (corn and cotton) predominantly anaerobic (rice); and (iv) three different agroecological zones. The specific objectives are to:

1. Assess the effects of Bt corn, cotton, and rice on the abundance and diversity of AM fungi and compare them to non-Bt isolines grown with and without insecticide in field trials.

2. Assess the abundance and community structure of detritivore arthropod populations in field trials of Bt corn, cotton and rice.

3. Determine residue decomposition rates, C allocation within plants, and fate of residue C in soil for Bt corn, cotton and rice grown under field conditions.

Accomplishments

- No effect of the Bt genotype was found on plant part decomposition rates, lignin content, mycorrhizae and microbial community measures in any of the years for all three crops, with two different Bt genes and in the several soil habitats studied.

- A primer set that provided both specificity and good coverage of AMF was identified from the several claimed to be useful for ecological studies of AM fungi and was successfully used to identify the genera colonizing corn roots in these trials.

- Detritivore populations colonizing crop residues were analyzed for corn and for rice in 2005. No differences in species abundance or species distribution were found due to Bt genotype for either crop.

- Litterbags harvested in 2005 showed that the major factor controlling residue decomposition was the depth of placement in the soil profile and the plant part (cobs, stalks, leaves or roots), and not whether they contained the Bt gene.

- Populations of bacteria and fungi colonizing corn residues were analyzed by T-RFLP. No differences in these populations due to genotype were observed. However, populations segregated based on depth of placement in the soil profile and by field history.

- In a ^{13}C-labeling experiment conducted in the greenhouse to study carbon allocation, the non-Bt corn isoline grew taller and accumulated more biomass than the Bt corn. Growth of the non-Bt isoline was also stimulated by low rootworm pressure (minor grazing).

Assessment

An important aspect of this project was its comprehensive nature in that it was a multidisciplinary assessment of the Bt genotype on several ecological processes reported or hypothesized to be potentially affected by the Bt construct. Such data is extremely **relevant** to the environmental acceptability of Bt crops, and helps pave the way for other biotech crops. Furthermore this methodology appears to be one of the few, if not the only, that tests for the effects of Bt crops on critical soil microflora and fauna. Given that the effects of Bt on soil flora and fauna appears to be one of the critical tests for allowing or not allowing the use of Bt crops, then this methodology has the potential to have a large, world-wide impact. The fact that the work was done in three major agricultural regions of the world makes it highly relevant to USAID and of potential **impact** to the acceptability of Bt crops internationally. All planned work has been done or is well on track to be done except for the fact that the third year of experiments in Colombia cannot be done because the soils research program there has been terminated effective August 1, 2006.

Nonetheless, the two years of results appear to be sufficient together with the data from other sites to support a no-Bt effect conclusion. The fact that all objectives are in line to be met indicates a high level of **performance** for this project. Furthermore, the methods used and measurements taken were sensitive enough to detect significant changes, should they occur due to cultivating Bt crops. All components measured in the field trials at all sites indicate that changes in environmental factors (within and between seasons) strongly influence all measured variables, hence the measures were sensitive enough to observe environmental effects. In contrast, the Bt genotype of corn, rice or cotton had no detectable effect on soil biota

or their activities. This comparison between environmental *vs.* Bt effects is a strong indication of the sensitivity and **quality** of the experiments.

Recommendations

2006-07—Remainder of Current Project

1. Complete studies on AM fungi, residue decomposition and detritivore arthropods for all cropping systems.

2. Repeat greenhouse trials to assess structural C with isogenic corn lines, a limitation to overcome a remaining uncertainty.

3. Summarize outcomes across all systems. Because of the comprehensiveness and uniqueness of this study, this is the highest priority remaining task.

4. Translate knowledge and results into policy framework.

5. Communicate these findings to the public.

6. Begin to gather quantitative information on the impact of Bt on other components, such as decrease in pesticide use, health effects such as the role of Bt on structural C and elemental uptake (Si, Mg, Ca etc.), and on palatability of forage.

If the concluding work continues to support the lack of environmental effects of Bt in crops, then it is critical to the advancement of GMO products that this work be used to inform policy making, communicate to the public and, using this case as a model, to extend to other GMO crops important in developing countries. The value of this advance is best captured by a timely follow-on.

2007-2009—Bridging Period

1. Work within international context on broader scale.

2. Extend the work to determine and assess a number of ecosystem services of soil –predictors/sentinels, useful to assess a variety of technologies or environmental impacts.

Field Support

Principal Investigators: G. Uehara and H. McArthur, University of Hawaii

Introduction

Field support is also referred to as "buy-ins," which are additional activities undertaken by the SM CRSP at the request of a USAID field mission. The most substantive field support activity was a two-year project entitled, *Timor-Leste Agricultural Rehabilitation, Economic Growth and Natural resources Management*.

Objectives

By strengthening the human and institutional capacity of the Ministry of Agriculture, Forestry and Fisheries (MAFF), the project will enable the Ministry and business community to work with the farming community to achieve the following objectives:

1. Increase agricultural productivity and food security.

2. Increase household incomes and create new employment opportunities.

3. Adopt farming practices that protect and preserve the environment for future generations.

Accomplishments

Objective 1

- Rice yields increased with the introduction of science-based diagnostic methods. MAFF (Ministry of Agriculture, Forestry and Fisheries) staff and farmers able to implement

ICM or integrated crop management system (IRRI) for rice and utilize the leaf color chart for nitrogen monitoring.

- Maize yields improved through soil testing with soil test kits introduced to MAFF to allow site-specific nutrient management of N, P and K.

Objective 2

- Candlenut oil extracting facility created new income source to local communities with establishment of small enterprise linkage between partners in Timor-Leste (T-L) and the U.S.

- Niche export markets for vanilla, honey derived from mesquite and black rice explored through contacts with small business entrepreneurs in the U.S.

Objective 3

- Participatory sustainable land management approach was introduced to MAFF and farming communities. The resulting partnership allowed farmers to have a say in which trees will be grown, where they were to be planted and for which farmer-specified purposes. The MAFF then established nurseries to cultivate these species.

Assessment

The project has shown the responsiveness, adaptability and relevance of the SM CRSP to opportunities presented by USAID field missions. In cooperation with the GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) Food Security Program, the initiation of the export of high-value candlenut oil to Hawaii has introduced a valuable source of income to Timor-Leste. The contribution of the SM CRSP consisted of: 1) liaising with the Hawaii-based customer and bringing him into contact with the oil producer in Timor-Leste; 2) developing the Timorese processor's business plan; and 3) facilitating technical training of oil processing as well as business training. GTZ's contribution was the selection of a potential Timorese producer, providing guidance and advisory services to him, and supporting him in getting the necessary bank loan to obtain the processing equipment. In the meantime, regular export of the candlenut oil took place. The project shows **relevance** to economic development through the fact that it is the first high value product (besides coffee) exported from Timor-Leste. The earned income is sufficient to cover likely future expansion of oil processing, or the diversification of production/processing if new opportunities arise in the future. The initiative supports farmers in the region through increased demand for candlenuts. Candlenut as such is an excellent income potential for farmers because it does not require investments from the farmers' side. The women of the household usually organize the cracking and opening of the nuts, so they earn equally from the demand created by the processing factory.

The project also included testing and demonstration of Integrated Crop Management (ICM). District-based Crop Officers of the Ministry of Agriculture have been trained on their own plots to improve their technical knowledge to be distributed to farmers. The technologies introduced did in fact increase the output of the demonstration plots. The low input practices recommended in the ICM are particularly suitable for subsistence producers.

The **performance** of the SM CRSP in this activity is remarkable because of the need to overcome the many challenges of working in Timor-Leste, with its poor infrastructure and underdeveloped business and financial sectors. In this regard the accumulated development experience together with the collaborative and participatory approach adopted by the SM CRSP have been key elements in their success.

OVERALL EVALUATION OF SM CRSP PROJECTS

Response to 1999 EEP Recommendations

During the 1999 EEP review and subsequent technical committee meetings, a concerted effort was made to emphasize impact (significant research output and outcomes) of the research programs and dispel the perception of an entitlement to conduct scientific studies and train graduate students. The current SM CRSP projects have all made significant progress in focusing on solutions to high priority problems, identifying customer's needs and transferring results. Although tremendous improvement has been made in this area, technology transfer and how to write and market project impacts remains a major challenge for the SM CRSP. In today's environment, SM CRSP impacts must be marketed to sponsors, stakeholders and intended users if support is to be continued. Some progress through in-country awareness raising by component projects has occurred, but the SM CRSP needs to address this need through some programmatic mechanism, with a commitment of resources to make it happen. Otherwise, the excellent discoveries and useful product coming from the SM CRSP will be relatively unknown.

Current SM CRSP projects are doing an excellent job addressing specific 1999 EEP review recommendations. *1) A greater focus be given to the integration by biophysical with socioeconomic approaches to soil management constraints, including more frequent face-to-face meeting, more discussion and dialogue among component projects, and more attempts at consensus building. 2) Enhance integrated approaches to soil management research within the SM CRSP; increase the focus on specific soil management constraints; use customers/stakeholders to help define the next set of constraints.*

At times during the review it was difficult to determine where one project stopped and another one started. As shown in the body of the text, the progress made during Phase 2 with integration of the biophysical and socioeconomic approaches and the collaboration among projects has been excellent. Likewise, the projects have an impressive assemblage of collaborators/ stakeholders and farmer focus groups with whom they have strong working relations.

The last EEP in 1999 recommended that each project should have a gender analysis component. Although gender analysis does not figure explicitly in each project's activities, researchers are sensitive to expected gender-specific effects in technology design and adoption. For example, adoption surveys on the early acceptance of the healthy-seedling technology in Bangladesh show that more than half of the beneficiaries in the vegetable and vegetable-seed producing sectors are women. Female farmers in Mali offered strong testimony of the benefits to diversification from their recent adoption of ridge tillage technology that increased tree densities and fruit production, groundwater availability and small-plot irrigated agriculture. The consequences from the ACN technology are especially favorable for women as they preferentially have greater use rights to tree production, "own" the home garden and irrigated vegetable plots and can allocate more time to more productive tasks than carrying water. Women scientists also figure prominently as partners. Professor Tasnee Attanandana is an SM CRSP NuMaSS principal investigator and the driving force behind site-specific nutrient management in Thailand and Dr. Madonna Casimero and Dr. Deanna Osmond, of the Philippine Rice Research Institute and North Carolina State University, respectively, are also NuMaSS principal investigators. Dr. Julie Lauren is one of the principal investigators of the Rice-Wheat Technology Adoption project at Cornell University. Dr. Medha Devare and Dr. Janice Thies at Cornell University are two of the principal investigators of the SM CRSP

biotechnology project and Dr. Melanie Correll at the University of Florida is an SM CRSP co-investigator on the Florida biotechnology project.

SM CRSP Impact Evaluation

Impact evaluation measures intended and unintended changes that can be attributed to a particular project or program. The question to be answered is what would the situation have been if the Soil Management CRSP program had not existed. This is distinct from process monitoring that was carried out over the two phases of the SM CRSP by the Management Entity, Technical Committee and Board.

With the SM CRSP portfolio of projects, increased agricultural training and education and outreach and adaptive research in the extensive rice-wheat regions of Asia have occurred. The same holds for maize areas in Southeast Asia, West Africa and Latin America. Not only is the SM CRSP training and outreach cost effective and robust, alternative sources like NGOs and relief organizations are not comparable in expertise.

With the SM CRSP portfolio of projects, there has been increased mobilization of in-country science and technology and capacity for innovation in agriculture and environmental studies. Examples include site-specific crop management in Thailand, soil and plant testing laboratories in Central America and West Africa, multidisciplinary analyses for strategic policy and tactical management support for benefits of carbon sequestration, as well as exploratory biotechnology research into effects of genetically modified crops on the soil environment.

The portfolio of SM CRSP projects relies heavily on information and decision support technologies that seems to be mobilizing transformational changes in collaborators. Armed with technologies that incorporate the latest scientific knowledge, like NuMaSS, collaborators indicate a greater sense of professionalism.

A weakness in impact evaluation of the SM CRSP is that individual projects have not always specifically documented target populations for project outputs and, to an even lesser degree, uptake pathways leading from development of outputs to adoption by end users. This is particularly important for the less traditional approaches using information technology. A "business plan" approach that helps quantify the "adoption gap" may appeal to potential donor agencies.

Science Quality

The science quality of the SM CRSP is excellent and reflects the focusing, maturity and management that has occurred since the 1999 EEP review. The experimental designs, quality control, statistical analyses, modeling and scaling revealed considerable attention to detail and use of the state-of-art methodology and knowledge. The only cases in which some limitations exist are those deriving from the limitations in facilities, reliable electrical power and staff stability in some situations in some countries. In these cases, the PIs are on top of the problem and doing their best to find alternative solutions. The steady progress in publication in peer-reviewed literature is an important benchmark for quality, as is the enthusiasm of developing country scientists to become involved in the projects. It is also noteworthy that the level of query and discussion among the SM CRSP project scientists is providing internally for a high level of critique and useful suggestions. Furthermore, the Technical Committee (TC) has excellent expertise for this subject and has provided advice annually that has shaped the projects. The greater focus and synergy among the current projects has enhanced the level of science exchange and hence science quality.

Responsiveness

The SM CRSP has responded to two emerging issues, carbon sequestration and biotechnology, and made important scientific advances in both. Furthermore, the SM CRSP undertook a field support activity in Timor-Leste in response to a request from the USAID field mission. That activity has been a singular success in developing an export industry for this new country.

Collaboration

Amongst the component projects, the strengthening of collaboration since the last EEP has been commented on in the section above. Outside the SM CRSP, the base established in the first phase for collaboration with developing country institutions and international research and development organizations has expanded considerably in the period under review. Particularly noteworthy is the cooperation with NGOs and the private sector in projects such as the rice-wheat work in Asia and carbon work in West Africa. Collaboration with the Future Harvest centers, developed country universities and bilateral projects is extensive and significantly enhances the spillover effects of the research tools and results produced by the projects. The Management Entity (ME) has exploited a number of opportunities to collaborate with other CRSPs including the peanut, INTSORMIL, Global livestock, Aquaculture, SANREM and IPM CRSPs.

Management

The overall management of the project has been good: PIs continue to appreciate the hands off approach of the ME; the rationalization of the project components following the last EEP was well managed by the TC and ME and tensions over funding levels have been overcome; the lack of synchrony between the transfer of funds and the need for those funds by the component projects has also been overcome; and the budget process is more transparent.

Communications of the ME and PIs with USAID, at both the mission and agency level are generally excellent, and this is reflected in the opportunities that the project has taken to get support for the work in Timor-Leste, and on carbon sequestration and biotechnology. Communication on administrative issues is good, but as the project enters its last year, more needs to be done to engage decision makers to convey the benefits and impacts flowing from the project. The Panel notes that changing priorities and staffing within USAID have the potential to affect the SM CRSP negatively, so the ME needs to be sensitive to the changes and respond to opportunities that may arise. Internally the ME and the PIs have taken advantage of the World-Wide-Web as a means to facilitate the transfer of reports as well as disseminate information to the general public. Earlier problems with communications over budgets have been resolved.

Planning in the project follows the format and guidelines established by the ME in the first phase. The Technical Committee continues to play a key role in providing reviews and oversight of the planning process. The meticulous planning on the current five-year phase should not be compromised by funding cuts in the last year, because it could seriously affect the deliverables in some component projects such as NuMaSS.

OVERALL RECOMMENDATIONS

Issues for Period of 2007-2009

The Soil Management CRSP has had impacts at the farmer, researcher, government decision maker and private sector levels. These include female farmers in Bangladesh and Mali finding new sources of revenues, researchers building on SM CRSP findings to develop science-based tools, the private sector using SM CRSP products to improve their services and government officials making better decisions. These successes are proof that the SM CRSP has responded successfully to the requests of their various clients.

However, in each case the number of beneficiaries is small compared to the potential number of beneficiaries. A major challenge for USAID and its partners during the years between the end of the SM CRSP (2007) and the start-up of the planned Soils, Water and Ecosystems Services CRSP (2009) is how to maintain the momentum needed to achieve the potential. Given the sunk costs, failing to maintain the momentum would mean a low return on US taxpayers' investments, compared to what could be achieved in terms of human impacts.

As can be seen from the above examples, the SM CRSP has contributed to at least three domains in the new USG Foreign Assistance Framework. Local governance has been strengthened as people have reason to organize and do things as members of a local government that they could not do as individuals. The environment has positively been affected as the technologies and decision-support tools help people create natural capital, reduce erosion and reduce pollution. Moreover, as we saw in a number of cases, livelihoods have been improved as the technologies and decision-support systems provide people with more profitable agriculture as well as new sources of incomes. Finally, we also saw remarkable cases where national and international institutions were strengthened such that they were in a better position to serve the farming population.

USAID's challenge and opportunity for the years between the scheduled close of the Soils Management CRSP (2007) and the initiation of the new soils-based CRSP (2009) will be to continue to follow or to accelerate the impact trend. Creating a hiatus during this period would likely put the brakes on the trend and substantially reduce returns to US taxpayers' investments.

To avoid a hiatus and reap the maximum returns, the SM CRSP and USAID must work collaboratively to lay out a plan that identifies promising impacts (and potential impacts) and actions necessary to keep the trend going. This would include identifying non-USAID sources of funding to allow beneficiaries to maintain contacts with the PIs (the counterparts told us that maintaining contact with the PIs was highly desirable) and other mechanisms. We also need to identify those activities that will be most strategic in achieving impacts. As part of identifying additional sources of support, PIs should take opportunities to engage decision makers in how the SM CRSP products could make their jobs easier in reducing poverty, strengthening economic growth and achieving similar important goals.

Recommendations on Future Priorities

We focus our comments on the proposed Soil, Water and Ecosystem Services CRSP scheduled by USAID for 2009. The new CRSP will address USAID priorities in the agriculture-rural sector in developing and transforming countries. The target will be tools, practices and methodologies that promote the maintenance or regeneration of the resource base in multi-use landscapes while increasing agriculture

and natural resource based income. These issues need to be addressed in the context of global environmental change driven by human population growth and development.

We contend that the Soil Management CRSP has laid a solid foundation for such a new CRSP, through not only the scientific and problem-solving dimensions, but also the collaborative capacity building in both institutions and people in developing and more advanced countries. The network of collaborators, whose strongly positive responses to the SM CRSP are documented in our survey, could become the core participants in the new CRSP. The SM CRSP has also developed valuable insights that could be used to target the new CRSP on degraded lands in the tropics, from the sandy soils of the Sahel to the overexploited lands of the intensive production systems of Asia.

The tools and technologies already developed in the SM CRSP can readily be adopted in the Soil, Water and Ecosystems CRSP. A key element is the systems approach, which places soil in a central position in the global water, nutrient and carbon cycles, and leads to improved understanding of impacts on humans of poor or improved soil management. Technologies such as the ACN in Mali and the permanent bed system in Bangladesh significantly improve surface and ground water balances in ways that improve livelihoods and agricultural productivity. The SM CRSP systems approach relies on the use of models that enhance the transfer of technologies, and facilitate the upscaling of site-specific measurements, such as soil carbon; for example, scaling up to river basin scales will be an important element of the new CRSP. Another tool is the trade-off analysis model that can be used to study ecosystems services at a landscape scale.

Finally, we note that biotechnology is an integral part of the SM CRSP and of ecosystem services in that genetically modified plants and plant associated microorganisms are a part of future lower-cost agroecosystems. Furthermore, molecular technologies are emerging for rapid, low cost methods to diagnose plant pathogens and control their dispersal, for monitoring groundwater water safety, assessing microbial biodiversity and as indicators of healthy ecosystem services. Biotechnology products will continue to grow as a component technology of more holistic approaches to sustainable agroecosystems in the developing as well as the developed world.

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APPENDIX II. SUMMARIES AND ANALYSES OF THE QUESTIONNAIRES

A Context for the Evaluation of the SM CRSP

The SM CRSP was initiated and developed in a period of time when many smallholding farmers in the developing world were struggling to move from subsistence farming to more intensified farming aimed at increasing their family's standard of living. As subsistence farmers, their margin between enough to eat and hunger was small. They were risk-averse and shaped their strategies to protect against the downside. As they transitioned to producing for increased revenue streams, they had to treat farming more like a business and take on increasing amounts of risk. This transition required new types of knowledge and technologies. These had to help them minimize risk even as they optimized investments in inputs and equipment. And, often, the knowledge had to be site-specific.

Based on the findings of this EEP, including the information from the questionnaires, the SM CRSP produced decision-support tools that allowed farmers, extension agents, merchants, and policy makers to make better-informed decisions. It also pioneered production technologies that both increased productivity and reduced risks. In most of the cases, these decision-support tools and technologies were within the means of producers and/or extension agents.

It was also found that most of the decision-support tools and technologies will require additional testing and refinement before they fulfill their potential of improving the livelihoods of millions of rural producers instead of improving the livelihoods of thousands.

Summary of Findings

The evaluators found that the SM CRSP produced high-quality products that provided smallholders, extension agents and decision makers with knowledge-based and science-based tools. It also produced technologies that provided smallholders with the means to increase productivity while reducing risk.

In the context of the countries where the SM CRSP worked, the development of the knowledge-based tools is timely. In these countries, a growing number of smallholders are struggling to move from risk-averse, subsistence strategies to intensified, commercial farming. The margins of most are still fragile and they require new types of knowledge that will protect against the downside even as it helps optimize returns to investments. However, until the SM CRSP, few knowledge-based tools existed that (a) provided information that focused on critical farm-level questions and (b) were within the means of smallholders and those helping smallholders. Moreover, few knowledge-based tools provided decision makers with ways to organize and analyze complex sets of data that constituted policy and institutional decisions. Furthermore, because the tools were science-based, they were more reliable and universal than non-science based approaches.

The SM CRSP also pioneered several technologies that addressed basic constraints to smallholders increasing productivity. These included technologies to capture soil moisture, to reduce insect damage, to provide micronutrients, to build soil organic matter and to increase input and labor efficiency. In each case, these technologies were aimed at providing smallholders with cost-effective means to take a next step in moving to an intensified system.

Finally, with a few exceptions, the Questionnaires noted that the above was done

while building human and institutional capacity to carry on the progress.

Summary of Questionnaires' Scores

(Scale: very high, **1,** through **2, 3, 4** to **5,** very low)

MEANS:

Overall:	1.84
Effectiveness:	1.80
Relevance:	1.56
Quality:	1.84
Capacity Building:	2.20
Potential to Achieve Goals:	1.79

Summary of Responses in Each Category

Effectiveness: Did They Achieve Their Objective?

With a few exceptions the evaluators said that the SM CRSP was effective. They noted the following:

- Decision support tools were developed that helped farmers, extension groups, researchers and policy makers make more effective decisions.

- Production technologies were pioneered that increased productivity for smallholders. Several noted that the technologies had substantial potential to have broad-based impacts because (a) they overcame fundamental production constraints and (b) they did not require resources that were beyond the means of most smallholders. In one case it was reported that thousands had adapted the technology.

- The SM CRSP spawned collaboration between groups that did not typically work together. The Trade-Off Analysis, for example, provided a tool that helped people from different disciplines to better appreciate the increased impacts from synergies across the disciplines.

- Training provided under the SM CRSP provided extension organizations and NGOs with science-based skills that increased their effectiveness.

- Collaboration with the SM CRSP helped national research institutes to focus on research that helped produce people-level impacts.

Relevance: Were Objectives and Work Relevant to the Country?

The SM CRSP is, above all, a knowledge management program that produces information that helps producers, policy makers, merchants, and donors make better-informed decisions.

Producers: Moving from subsistence to intensified agriculture farmers will need to treat farming more like a business. Each year, subsistent farmers use their considerable knowledge to coax enough food from the year to ensure that their families survive. The margin against having too little food is small and they are forced to protect against the downside; reducing risk is their strategic cornerstone.

As more farmers shift toward a strategy that will improve their family's standard of living, they must shift from risk minimization to input optimization. This transition brings new knowledge needs. During this period, they will require information that allows them to intensify with the least exposure to risk. And, given the variability in climate and soils, much of this information will have to be site-specific as well as timely and cost-effective.

The evaluators scored the SM CRSP as highly relevant on helping people make decisions that optimized gains while minimizing investment costs. The decision-support tools that the SM CRSP pioneered were reported to provide farmers with information about outcomes and risks from investments in fertilizers, pesticides, improved seed, technologies, equipment,

etc. These and other decision-support tools provided extension agents and input dealers with the means to provide better advice to farmers (thereby helping to professionalize the industry). And, strategic decision-support tools like the Trade-Off Analyses, provided policy and other decision makers with tools to make strategic policy and institutional decisions.

The evaluators also noted that the technologies pioneered by the SM CRSP were relevant on two critical points. First, the innovations such as ridge tillage, "healthy-seedlings," solarization, micronutrient applications and carbon-building agriculture all replied to basic problems faced by millions of farmers. Second, each was within the means of most producers.

The microbiological research was not evaluated by collaborators but was assessed by the EEP. Here too, the research was focused on overcoming fundamental problems facing the development community. In this particular case, the community was faced with the question of what would happen to soil microflora and fauna. The pioneering work by the SM CRSP provided both a science-based process to addressing the question and preliminary answers to critical questions.

Quality

"The science in the project is state-of-the art." Many Questionnaire responders echoed this assessment. There was sincere appreciation by collaborating scientists and laymen of the high quality of research conducted under the SM CRSP. This was attributed to the strong and conscientious leadership shown by the Principal Investigators. It was also a reflection of their professional expertise and knowledge.

Peer-reviewed articles and demand for training were two measures of the quality of science and research. Perhaps more poignant, however, was the motivated collaborators such as those who continued to conduct research in Nepal and Bangladesh where domestic problems made it difficult to carry out the research.

There was also recognition on the part of the collaborators that the SM CRSP was providing them access to state-of-the art research and scientific tools.

In a few cases, it was noted that particular knowledge systems did not produce reliable information. However, these were the exceptions that showed that additional refinement would be required.

Capacity Building

The SM CRSP's training programs increased capacities across all levels and topics.

Potential to Achieve Goals

The potential of the SM CRSP to contribute to development goals is rated highly. The comments generally refer to increased yields and income, improved decisions and better management of soil and water resources and improved food security for poor beneficiaries in marginal areas.

Samples of Responses to Questions

The following responses were selected from the 25 Questionnaires. In the pressure to select a response that represented a number of responses, we probably erred on providing too many samples.

Question 1. Please assess each of these major projects/activities in the table below according to the following criteria (*Please, tick with* ***X):***

Effectiveness:

1) TOA

a. Project has been effective in disseminating TOA methodologies in the region and

government research institutions and universities in the region are using the tool in various projects.

b. TOA methodology compels experts in different fields to work together.
c. Supporting institutions through data analyses to evaluate technologies and training, have been key to generating and transferring scientific knowledge and capacity to local institutions via TOA applications.

2) NuMaSS

a. Objectives in term of fertility advice and carbon stock determination were met.
b. SM CRSP activities are effective in developing sustainable technology for improving soil nutrient conditions.
c. NuMaSS has been proven a good diagnostic tool as it provides good information on which major elements are lacking based on the soil analysis and it has a very good predictive capability of determining the fertilizer and lime requirements for corn and upland rice in acid uplands.
d. Economic analysis also showed an advantage when farmer's use the NuMaSS as a decision aid tool in managing their fertilizer for upland corn in Luzon and Mindanao sites.
e. Standard method for laboratory was defined.
f. Improved standard of living, reduction of debt, more saving and happy lives of the farmers who used site-specific nutrient management.
g. The project is effective in helping local farmers identify nutrient deficiencies.
h. The strategy in selecting developing country collaborators should be revisited.
i. Networking among SM CRSP researchers needs improvement.
j. This research activity is a first in the Philippines and will accelerate agricultural development.
k. The collective activities in eight countries, encompassing nine commodities, seven soil orders and four major agro-ecosystems provides the desired collective settings by which to (a) test and compare NuMaSS with local practices, (b) refine software components that limit adoption and (c) monitor the adoption process under a variety of conditions.
l. The project is effective in helping the local farmers identify the nutrient deficiencies in their farmlands. The treatments clearly show the difference of soils amended by fertilizers and lime, and those that were not applied.
m. The NuMaSS has been proven to have a good diagnostic capability as it is able give a good information as to which major elements are lacking based on the soil analysis and it has a very good predictive capability of determining the fertilizer and lime requirements for corn and upland rice in acid uplands. The target yields are attained in favorable environments (absence of climatic disturbances such as drought and typhoons) in Luzon and Mindanao sites. It has been proven to be comparable or even better than the current regional recommendation as it takes into account the long-term sustainability of the upland areas in terms of ameliorating the acidity of the soil. Yields were either comparable or higher than the regional recommendation and the current farmer's practice. Economic analysis also showed an advantage when farmer's use the NuMaSS as a decision aid tool in managing their fertilizer for upland corn in Luzon and Mindanao sites.

3) Healthy Seedlings/Rice and Wheat Systems

a. Technologies were effective as it contributed to substantial yield increases for both rice and vegetables.
b. Farmers produce enriched seed and observe higher yields using micronutrient-

enriched seed in micronutrient deficient soil. However, they are producing micronutrient-enriched seed in small scale.

c. The program has been effective at raising the awareness of thousands of farm households about Healthy Seedlings through partnerships with NGOs having relatively large coverage (CARE, RDRS).
d. Healthy Seedlings have shown increases in the prices of vegetable seedlings and produce along with higher yields. New economic opportunities have opened up for resource poor farmers (seedlings, flowers, vegetable produce) and service providers (plastic supply). In addition to yield benefits, private companies who purchase maize from farmers to supply the rapidly expanding poultry industry in Bangladesh are promoting the use of lime. The Permanent Raised Beds technology was developed partially in response to reduced labor supplies and increasing labor and input (water and fertilizer) costs. Farmers involved with this activity are reporting reductions in tillage, seed and water costs, while tillage service providers are seeing new business opportunities (tillage-bed formation for hire).
e. We have identified key factors that encourage or limit adoption/scaling up of soil management technologies.
f. Technologies were effective as it contributed to substantial yield increases for both rice and vegetables.
g. Farmers observed positive liming effects on maize and rice yields and are convinced to apply lime. Many farmers are using lime in Patgram area in this season**.**
h. Farmers who are involved with this project producing enriched seed and getting higher yield using micronutrient enriched seed in micronutrient deficient soil.
i. However, they are producing micronutrient-enriched seed in small scale.

4) Carbon

a. Studies showed that changes in soil and crop management can lead to increases in soil C in Ghana & Mali.
b. This project has been effective at helping Nepali soil scientists identify and correct accuracy problems with their soil organic carbon and texture measurements. From new and existing data we have been successful in developing texture-soil carbon algorithms for cultivated and native soils in South Asia and using [them] to estimate maximum potential carbon sequestration for selected test sites in Nepal. Furthermore we have quantified soil organic carbon gains under specific tillage and residue management practices in the rice-wheat cropping**.**
c. Increasing soil organic matter in soils promotes natural resource conservation (water, nutrients). These impacts are being demonstrated at our experimental trials with zero tillage, minimum tillage and farmer trials with permanent raised beds.
d. It is high as objectives were achieved accordingly.
e. Activities were carried out with higher precision and carefulness from the beginning.
f. The stated objective of assessing soil carbon sequestration by agricultural systems in the locality may not be realized within the project time frame because it might not be easy to detect the changes in soil C. But the project is using modeling approaches and this in my view may be able to show the potential of some cropping systems to sequester soil carbon.

Relevance:

1) TOA

a. TOA offers an integrated assessment framework for answering complex questions arising from multiple goals such

as reducing poverty and environmental degradation which are in line with Kenya's Economic recovery strategy, USAID objectives and Millennium development goals.

b. Project objectives of disseminating TOA methodology is timely with institutions in the regions looking for a practical tool to support informed decision making. Contribution of these projects is very relevant to strengthening of national expertise.
c. Issues of policy impacts on sustainable development and poverty rank very high in host country strategies to reduce poverty and promote development of the ag sector.
d. Several studies consistently demonstrated soil fertility decline in Mozambique as fundamental problem. Supporting national forum of integrated soil nutrient management, promoting exchange of information among Mozambican young soil fertility scientists and developing sustainable soil fertility management practices have very positive contribution for improving crop productivity and poverty reduction.
e. Project is very relevant to soil fertility management, which is a major agricultural problem in the Tropics.

2) NuMaSS

a. Project is relevant since soil fertility is a major constraint to increased crop production. Any effort to increase soil organic matter and soil fertility is important.
b. Project is relevant in providing a decision tool for site-specific nutrient management. Farmers need a tool that would reduce fertilizer costs and increase yields. Extension agents and farmers collaborate about site-specific nutrient management in the upland areas. The acidity module has been exceptionally relevant and shows improvements in the soil acidity with lime amelioration. Farmer led extension demonstration farms were set up by the Regional DA office to demonstrate the effect of lime and balanced fertilization for corn. Extension agents were trained on use of NuMaSS and linked key soil test laboratories and universities.
c. It is highly relevant (2) as there is accuracy and precision in daily soil routine analysis after inclusion of reference samples.
d. Project is more relevant to big farms as opposed to small farmers (i.e., Leyte). Farmers in Eastern Visayas are not willing to invest on fertilizers although they acknowledge the importance of fertilizer application. In addition, the NuMaSS software is soil test based. Unfortunately, Philippines has only few soil testing labs which can handle the analysis required by the software.
e. The project is very relevant in terms of providing a decision tool for site-specific nutrient management. This simplified guide has translated scientific terms into layman's language within the reach of extension workers and even farmers.
f. NuMaSS enables users to compare the agronomic, economic and environmental consequences of nutrient management needs among different crops, soils and available nutrient sources.
g. NuMaSS algorithms to assess P requirements do not work in soils dominated by amorphous clay mineralogy (Andosols). Our investigations on P fertilization in these soils seek to identify alternative soil proxy variables for the P algorithms, and should also be of relevance to this soil group in Africa and Asia.
h. This ability to evaluation and select from different local scenarios should, hopefully, contribute in a positive manner to USAID's priorities on improved food availability, economic growth and over-exploitation of natural resources.

i. The project is very relevant considering that the provincial government of Negros Occidental is boosting its corn production to meet the demands for livestock and poultry industry (i.e., corn being produced mainly for feeds).
j. Practices that increase soil C also lead to increased crop production by increasing soil fertility and other characteristics.

3) Healthy Seedlings/Rice and Wheat Systems/Permanent Raised Beds

a. Technologies are relevant and easy to master by poor farmers. Technology is cost effective and inputs (polyethylene plastic) available in local stores.
b. System yields continually decline (India, Pakistan, Nepal etc.) from depletion of soil fertility. Project priority improves soil health and sustains system yields.
c. More than 50 percent of cultivated soils of Bangladesh are acidic, reducing crop productivity. Farmers should apply lime to ameliorate soil acidity and improve soil health for getting expected yields.
d. In the expanding vegetable and maize markets of Nepal and Bangladesh, increased production, better produce quality and more sustainable systems are elements for increased profitability and improved livelihoods. Healthy Seedlings have shown increases in the prices of vegetable seedlings and produce along with higher yields. New economic opportunities have opened up for resource poor farmers (seedlings, flowers, vegetable produce) and service providers (plastic supply). In addition to yield benefits, private companies who purchase maize from farmers to supply the rapidly expanding poultry industry in Bangladesh are promoting use of lime.
e. The Permanent Raised Beds technology was developed partially in response to reduced labor supplies and increasing labor and input (water and fertilizer) costs. Farmers involved with this activity are reporting reductions in tillage, seed and water costs, while tillage service providers are seeing new business opportunities (tillage-bed formation for hire).
f. Impacts on economic growth have only been observed with the permanent raised beds.

4) Carbon

a. Bangladesh soils are already deficient with some micronutrients (like Zn, B) and some micronutrients are becoming deficient (like Mo, Mg, Mn). Practice of applying micronutrient is rare in Bangladesh and farmers are not getting good yield in micronutrient deficient soils.
b. The project is relevant in that soil fertility is a major constraint to increased crop production and therefore food security in North Ghana. One of the mandates of SARI is the development and transfer of technologies that can improve soil fertility, which in my view is what this project seeks to do because by increasing soil organic matter, soil fertility/quality is increased. Therefore any effort towards increasing soil organic matter content and therefore soil fertility is important.

Quality:

1) TOA

a. It offers an all inclusive, high quality and scientific method of research.
b. The science in the project is state-of-the art. This is demonstrated by the publications and demand for training.

2) NuMaSS

a. High quality results are achieved. The guide is developed through the concerted efforts of technical experts in the field.
b. The project has implemented a good quality adaptive research. The needs of the target client (the farmer) were a big factor in implementing the project. The

feedbacks of the farmers and the extension agents were gathered so as to improve better the implementation of the project.

c. Valuable lessons were acquired during on-farm and on-station trials which will have positive contribution to technical performance of Mozambican young soil fertility scientists.
d. The project exposes me to the advances in diagnosing nutrient constraints and predicting fertilizer needs. However, in the case of our validation trials, the software failed to detect nitrogen needs of the area, which we attributed to very low phosphorus content of the soil.
e. The project allowed: 1) local users and scientist to get acquainted with most limiting soil factors related to crop nutrition, as well as to the use of computer based decision taking process; 2) project participants to maintain international contacts needed to remain actualized; and 3) in the case of Costa Rica, a few students have the chance to complete their research work needed to obtain their Master and Bachelor degrees.
f. To avoid duplication and to identify knowledge gaps, our starting point with each collaborator was to access their existing information. Replicated field and lab trials were designed to not only "validate" NuMaSS predictions, but also to acquire crop and soil specific coefficients which would enable users to "adapt" NuMaSS to their regional conditions. Issues of analytical quality of laboratories, whenever present, have been addressed by comparing local results with data from a certified laboratory.
g. Data collected have sufficient scientific quality for any purpose.

3) Healthy Seedlings/Rice and Wheat Systems/Permanent Raised Beds

a. Environmentally sound technology-soil borne pathogens eradicated without applying external inputs, accessible to farmers and impact lasting more than one crop cycle.
b. Requires no sophisticated measures for field application.
c. Need some appropriate tools in respect of water measurement seeding, fertilization, measurement of soil microbes and enough analytical facilities to ensure for a quality works.
d. Producing micronutrient-enriched seed is a simple and easily handleable (sic) technique.
e. The cost of lime (dolomite) is affordable by the farmers.
f. The quality of collaborative research with NARS and various NGO groups has been very good. All are committed to their programs and work hard. Upper-level management has been very cooperative and encouraging. Ideas for program activities and discussions about results are free flowing between international and national partners. Despite impediments such as the Maoist insurgency in Nepal or nationwide strikes in Bangladesh, our national collaborators are very motivated to continue and find ways to work around or adjust to these troubles. Equipment or methodological problems by our NARS collaborators periodically limited the timely output of required data. But we helped with technical advice and equipment backup in these circumstances, so activities could move forward.
g. Producing micronutrient-enriched seed is a simple and easily handleable (sic) technique.
h. The project combines both research on-station and on farmers' fields with systems modeling and remote sensing to achieve the project goals.

4) Carbon

a. Research Quality is good. We have received support from students from

University of Florida, USA and also from our sister Department of Crop Science, University of Ghana to ensure that data quality is high.

b. Some of the latest technologies and knowledge are being used in this project. Remote sensing, modeling, and advanced instrumentation are coupled with Conventional field experiments; these same methods are state of the art in the USA.
c. The quality of the project is high because it combines both science and technology transfer.

Contribution to capacity building:

1) TOA

a. Scientists in research institutions and universities in the region have been trained at different levels and CIP has strengthened capacity of TOA team in the region. Scientist from National Agricultural Research Institutes and Universities in the region are using the methodology in other projects**.**
b. Although a large number of people have been trained, some of the tools require further simplification to be widely used by policy advisors.
c. Formal training sessions and follow-up have been effective in building capacity within collaborating institutions.
d. Formal training sessions and follow up have been effective in building analytical capacity within collaborating institutions.

2) NuMaSS

a. With this project, it is possible and doable to make the uplands areas, which are very marginal in terms of soil fertility, become highly productive. As we will be experiencing high population and water problems in the favorable environments in the future, the uplands will eventually become significant in contributing for food production and food security for the developing countries.
b. The African-speaking training workshop and National workshop held in Maputo created awareness about the problem of soil fertility and allowed exchange of information among agricultural extension, research officers and NGOs. My MSc. training program, partially support by SM CRSP, is valuable contribution to the benefit to the country.
c. The training of researchers and farmers were supported by this project.
d. The project funds do not offer much for capacity building for the institution. There are no allocations for purchase of equipment that can be used for the project.
e. The project was made operational by involving about 20 undergraduate students major in Soil Science of University of Southern Mindanao. The students joined the team by batches to help and learn by experience how to identify soil series. The 2006 activities will include the training of extension workers on how to use the Simplified guidebook for Soil Series identification in Cotabato province. The extension workers will have a tool to use to better understand the soil in the area of responsibility. This is the first time that a tool has been developed for farmers and extension workers to understand soil classification and its use to understand soil constraints in the field.
f. The project allowed: 1) local users and scientist to get acquainted with most limiting soil factors related to crop nutrition, as well as to the use of computer based decision taking process, 2) project participants to maintain international contacts needed to remain actualized and 3) in the case of Costa Rica, a few students have the chance to complete their research work needed to obtain their Master and Bachelor degrees.

g. Information generated not always contributes fully to capacity building of the country. The main reason is the lack of strong research and extension programs.
h. Since the project's overall goal is to 'support the adoption of NuMaSS-based knowledge by on-going programs throughout Latin America', we have focused on capacity development within our groups of collaborators rather than the traditional SM CRSP approach of advanced training at U.S. universities. Our hands-on training workshops with NuMaSS and invited presentations at regional conferences/symposia have focused not only on software mechanics, but also on developing user understanding of the algorithms behind acidity, N and P predictions and the impact of the different variables involved. Inherent to the field and laboratory trial activities is an education process by which collaborators learn methodologies that can be used to nurture and sustain the software with information that is critical to its desired performance within their respective domains.
i. There is no contribution from collaborator for the capacity building in term of soil lab equipments and human resources.
j. The project has trained one Ph.D. in Soil Science at the University of Hawaii. We have trained 30 extension agents each in Region XI (South Cotabato) and Region II (Isabela, Cagayan, Quirino and Nueva Vizcaya) on how to operate the NuMaSS. We will be moving towards farmer education by setting up farmer field schools in the sites to facilitate better understanding about the importance of proper fertilizer management in growing a healthy crop starting wet season of 2006.
k. Senegalese scientists collaborating with the Project have a good command of software manipulation and methodology to assess carbon stocks.

3) Healthy Seedlings/Rice and Wheat Systems/Permanent Raised Beds

a. We trained and showed the farmers how to produce enriched seed by setting trials through project and farmers can produce and preserved the enriched seed for next year crop production.
b. Farmers who came to the touch of the works already know why, when, how much and how [to] apply the lime.
c. Most obvious capacity building activities have been the frequent training programs for our technology transfer partners and various farmer groups on Healthy Seedlings, Permanent Raised Beds and Liming. In addition bringing NARS scientists and technology transfer partners together has raised each other's awareness and understanding about what they do, what their needs are, and their limitations. This knowledge encourages routine interactions between these groups, and builds sustainable linkages and relationships that will last beyond the project.
d. At the individual level, the project has interacted with the RDRS Student Intern Program by funding the research of a Bangladeshi MSc. student on adoption of Healthy Seedlings by participants of CARE IPM Farmer Field Schools. Research undertaken by the SM CRSP to test permanent beds (initial experiment station work) and develop lime recommendations for Bangladesh has supported two Bangladesh Agricultural University Ph.D.s and one Rajshahi University Ph.D. At Cornell, one MSc. and two Ph.D. programs have been supported by this project.
e. During the field visits we exchanged our knowledge among the visitors. We also trained our research assistant, laborers and some interested farmers for a limited scale.

4) Carbon

a. Senegalese scientists collaborating with the Project have a good command of software manipulation and methodology to assess carbon stocks.
b. More reliable carbon and texture measurements can now be made in Nepal after working with NARS soil scientists to assess and improve their methodologies. In addition GIS and geostatistical capabilities in Nepal have been improved by interactions with the SM CRSP. Student-supported research related to this project has included seven MSc. students at the Institute for Animal and Agricultural Sciences, Nepal and one Ph.D. at Cornell.
c. At the institutional level, the project has provided equipment (automatic weather station, soil moisture meter, digital camera, GPS and a computer) for the research. Project funds was also used to purchase laboratory equipment in-country, reagents and a drying oven. Plans are far advanced for me to visit the University of Florida as a visiting scientist to work on aspects of the project.
d. This project is training a number of graduate students (US and West Africa) in use of remote sensing, modeling, instrumentation. Additionally, training programs are held for researchers in the different countries on methods for research on soil fertility and carbon sequestration.
e. There is no contribution from collaborator for capacity building in terms of soil lab equipment and human resources.
f. Two graduate students have completed their research Thesis within the project, another graduate research is on going and another will begin from May 2006.

Actual/potential contribution to development goals:

1) TOA

a. The ability of the TOA methodology to evaluate development potential of available technologies and policy options in an integrated framework and to answer complex questions arising from pursuit of multiple goals make it appropriate for policy advise in our complex farming systems.
b. The type of tools and methods being developed in the projects are the ones needed to address MDGs in agricultural systems.

2) NuMaSS

a. Better knowledge on fertility management is achieved.
b. As result of 16 years of civil war and lack of human resources few studies in soil fertility was conducted in past. There is no research agenda to address the problem of poor soil fertility. Bringing different stakeholders from NGOs, extension and research to present their experience and discuss how to move forward on ISNM in Mozambique was an impressive starting point. The soil fertility survey in different agro-ecological zones of Mozambique provided valuable information of responsive condition to soil nutrient management and amendment needs. On-farm and on-station trial was interesting beginning toward development of fertilization needs for middle-income farmers.
c. The SM CRSP has a very high potential of contributing to the development goals. With this project, it is possible and doable to make the uplands areas, which are very marginal in terms of soil fertility, become highly productive. As we will be experiencing high population and water problems in the favorable environments in the future, the uplands will eventually become significant in contributing for food production and food security for the developing countries.
d. The potential contribution to development goals is high. Solving the soil deficiencies among farmlands in Negros will lead to the improvement of the productivity

of these farmlands, hence, giving more benefits and advantages to the farmers.

e. The project component on Simplification of Soil Series is the much-needed input in making operational the scientific agriculture in the provinces. The master plan of the local government units should be coupled with the information of the soils in their area of responsibility. The food security issue could be better addressed by knowing the constraints and potential of the soil. The LGUs have been waiting for this kind of research.
f. The findings of the project, in conjunction with other political decisions, will provide better tools for better decision making process in crop nutrition, help in reducing production costs and environmental damage, lowering dependency on imported agrochemicals and increasing competitiveness of Latin American producers.
g. Adequate nutrient management and nutrient use efficiency contribute to satisfy food demand in a sustainable way.
h. Collaborators are putting into use a NuMaSS that has been tested and adapted to their local programs and conditions. Our frequent question to them is "how do you plan to use this"? We are very encouraged by the ideas and strategies in their replies and are working towards documenting impacts for the innovative approaches they will undertake.

3) Healthy Seedlings/Rice and Wheat Systems/Permanent Raised Beds

a. After five years study, our implications are: Permanent Bed with straw retention is a tool to produce higher yields; it saves irrigation water and seeds; permanent beds will also shorten the turnaround time, which affects system yields.
b. Increase the yield both of wheat and rice using enriched seed and increase the income of the farmers.
c. Livelihood improvement of farmers' community through increasing production, quality products and income generation.

4) Carbon

a. The project is contributing to improving food security of the farmers we are working with. Farmers have recorded higher maize yields as a result of the project compared to their own practices. So potentially, the project can contribute to improving food security if the cropping systems being tested are adopted.
b. This project addresses two major development goals: (1) food security via higher and more stable production, and (2) sustaining natural resources via improvements in soils, greater water use efficiency and potential contribution to reduced greenhouse gases
c. The project has entered a phase of on-farm trials with farmers: The soil management techniques extended to farmers have been very well accepted. Monitoring is continuing to evaluate improvement of on-farm productivity and soil carbon accretion.
d. Livelihood improvement of farmer community through increasing production, quality products and income generation
e. Contributed to improved livelihood security of rural poor households.

Question 2. Given the SM CRSP's mandate for innovation in agricultural research, what should be the SM CRSP's priorities? (Please identify the priority areas on which SM CRSP should focus its work).

For the next 2 years:

- Capacity building and enhance training of scientists, agricultural stakeholders (policy makers, NGOs) in developing countries with particular emphasis in soil nutrient and carbon management to improve soil and crop productivity.

- Enhance technology/information transfer to farmers, integrate farmer education through farmer field schools, enhance availability/ distribution of technical information materials.

- Building NARS-NGO-farmer linkages; understanding, addressing and documenting constraints to adoption of soil management technologies; targeting and scaling up strategies.

- Improve productivity of marginal lands and sustain productivity of irrigated lowlands. Continue focus on barriers to productivity for small farmers, especially on highly degraded lands (excessive leaching, severe compaction, severe soil erosion, frequent fire, and extensive weed infestation).

- Strengthen link between scientists and policy makers by increasing their demand for scientifically-derived policy advice.

- Improving soil analysis laboratory capability (new instruments, GIS).

- SM CRSP projects should complete the five-year plans that were meticulously designed, reviewed and revised during the competitive planning process. Shifts in priorities for the last 12 months can severely compromise the projects' deliverables.

- Further analysis of economic and environmental impacts of research innovations; documenting and modeling impact of novel soil management practices for rebuilding soil carbon in cultivated tropical soils.

- Validation of DSSAT-CENTURY and its application to evaluate alternate fallow management systems on soil and crop productivity.

- Additional research programs on 1) conservation agriculture, 2) low input/ organic agriculture, 3) micronutrient enriched seed, 4) lime management, 5) integrated water harvesting or water management, 6) analysis of soil management to increase productivity, improve soil quality, increase water use efficiency, and 7) analysis of benefits of reducing greenhouse gases.

- Additional extension /education programs to 1) provide associated nutrient management tools (leaf color charts, visual nutrient diagnostic tools soil series identification keys, and crop suitability maps), 2) translate NuMASS into Spanish.

- Identify other local research partners that could mutually benefit among participating agencies/organizations

In the soil and water field for the long term:

- Soil/water management for crop production and environmental quality, including fallow systems. Assess impact of payments for environmental services to protect soil and water resources. GIS technology could be incorporated into programs to assess regional soil and water resources and management impacts.

- Initiate/continue long-term research on soil health and water issues on national and global interest.

- Invest in training at higher level for more scientists from the region.

- Fine-tuning knowledge on different carbon compartments.

- Strengthen economic component of the research.

- Evaluate contribution of organic fertilizers into NuMass, using on-farm trials.

- Moving further towards natural resources management would be a good area to go into and combine it with educating the farmers and extension agents.

- Additional research to evaluate impacts at ecosystem/landscape scales; optimize conservation agricultural practices to encourage/facilitate adoption; and address constraints that arise in response to system modifications.

- Detail research need on micronutrient of Bangladesh soils especially on Zn, B, Mo and Mn.

- Research soil chemistry changes due to lime management and develop regional lime requirement maps.

- Identify problem soils in the country and then analyze the economic, historical benefits to management on constituents living in the problem soils areas.

- Identify WATERSHEDS that are critical in sustaining production both for human and animal consumption.

- Monitoring of the heavy metals in the rice fields is needed in anticipation of possible contamination.

- Expand GIS-based research in the low-bearing capacity highland volcanic soils.

- Increase research on forest nutrition and fertilization on forestry species in agroforestry systems, including soil fertility management, soil physical characterization and development of appropriate farm machinery.

- Add a K component and application to additional crops in NuMaSS. Continue to simplify decision support systems, making them accessible to small holders and extensionists while being adaptable for application in precision agriculture.

- Enhanced research and education (decision support system) on soil conservation management in steepland areas.

- Evaluate eutrophication of surface waters that accompanies intensive agricultural development.

- Develop technologies that increase efficiencies of nutrient and water use and that lead to more sustainable production. Develop tools for assessing improvements at a local level but are applicable globally.

Question 3. In your opinion, what are the constraints to the SM CRSP's impact?

- The major constraint to SM CRSP impact is the prevailing socio-economic conditions in the country, limiting farmer's adoption of technologies. For example, to increase soil carbon, productivity must increase, which is constrained by high input prices (no subsidies) and low farm prices. Farmers perceive that most soil management technologies and policies do not translate to enhanced on-farm profit.

- Increase project funds to enhance human resource development (researchers and stockholders) to achieve the impact of SM CRSP. Need resources for vehicles to help reach more farmers in rural areas and in different agro-ecological zones. Increase farmer interaction with on-farm studies, and number of participating farmers.

- Economic analyses are lacking, limiting the potential of SM CRSP research to effectively impact the adoption of research innovations.

- Low demand for the soil management policies by decision makers.

- Computer hardware and training needed by local extension agents to run NuMaSS.

- Regular soil analysis needed to generate fertilizer recommendation is laborious and expensive especially for the Ca, Mg and Al.

- Enhance linkage with the private sector input suppliers to promote healthy food production. SM CRSP too focused on development organizations.

Question 4. In your opinion, what can be done to overcome the above constraints and enhance the impact of the SM CRSP?

- Enhance participation from/involvement of stakeholders (farmers, decision makers, extension agents, private sector specialists, etc) on the need to invest in soil management for future productivity and sustainability.

- Allocate more resources to SM CRSP to extend field trials to other locations, enhance collaboration between field researchers and donor and increase cross visits between sites within the countries.

- A pilot project (for five years or so) might be required to actually evaluate the impact of adopted technologies on farmers' incomes and livelihood. Establish a critical period when soil analysis in repeated to evaluate the appropriateness of the generated fertilizer recommendation.

- Require full economic analysis component that is well integrated in the corpus of research from other disciplines. Development mechanisms so that government complements international supporting initiatives. Improve soil diagnoses facilities.

- Encourage local government to invest in computers for agriculture extension agents.

Question 5. Do you think the SM CRSP has any unique advantages as a collaborator over other institutions providing similar services?

[24] **Yes** [0] **No**

Yes:

- SM CRSP has internationally renowned scientific and practical expertise in tropical soil management and remedial technologies that share and apply this knowledge with that of local experts, who gain new knowledge and skills. The level of collaboration is outstanding, with the projects providing excellent technical and other infrastructural support. SM CRSP facilitates close relationships between PIs, collaborating scientists, partner organizations and farmers collectively working towards innovation and enhancing technology adoption. Other institutions do not invest as much time for intellectual/technical interactions and building relationships as the SM CRSP. Land Grant universities still have an edge (over large national or CGIAR centers) because of the strong links between teaching, research and extension. The multidisciplinary research and integrated analyses through inter-SM CRSP project collaboration adds value to the research investment. Despite limited resources, the projects are highly successful due to the active collaboration between parties.

- NARS are developing research projects that are more responsive to farmers needs (more on-farm research) and are addressing new problems/constraints rather than repeating the same experiments. They enhance socio-economic status of farmers and communities through income generation.

- SM CRSP has advantages relative to other competitive grants in that it provides continuity over five or more years, helping ensure that the

host countries carry technologies and methods forward, and that the project emphasizes the training needed to for technology adoption.

- SM CRSP is a pioneer to initiate research based on national and global interest. This is a unique advantage compared to other programs.

- SM CRSP emphasizes human resource capacity building while other projects focus on research only.

- NuMaSS is available for free to professionals working in the tropics. It represents a tool that considers information relevant for this type of an environment, instead of using unrelated knowledge developed in temperate regions.

Question 6. Do you think the SM CRSP has any specific disadvantages as a collaborator over other institutions providing similar services?

[14] **Yes** [9] **No**

*Yes***:**

- SM CRSP's budget is limited considering its potential global impact. Limited funds to facilitate research and human resources development compared to other USAID funded organizations. There is no provision for training and yearly visits of collaborators to different countries within SM CRSP's solarization activities. Since collaborators were from far distances considerable resources were used for visits. SM CRSP does not provide for capital equipment such as vehicles, which are badly needed by host scientists to conduct the work. Hiring or renting vehicles for project activities is too costly. SM CRSP does not provide for short- or long-term training for host country scientists and technicians. NARS and their administrators often prefer involvement with large "donors" with higher funding levels and fewer expectations for collaborative input.

- Very slow on project expense reimbursement.

- SM CRSP is not on top of congressional demands on USAID. USAID and its projects are not well seen in several countries.

- Cultural differences sometimes affect project implementation.

- The university system, by its very own nature, is slow to react and cautious. For-profit consulting companies and international centers are more adaptive and capable of responding to requests with limited lead time.

No:

- Current project has led to greater cooperation among researchers than previous projects. Outputs from the project include some generic tools and approaches that can be applied elsewhere and can be used by co-operators after the project ends. Notable progress was made via cooperation by the carbon project with the TOA project, with involvement of soil scientists, systems modelers/analysts, economists, agronomists and social scientists.

- SM CRSP is providing more or less similar facilities like other institutions to do similar type of works/research.

- NuMaSS complements other tools available to decide on fertilizer management recommendations rather than a competing tool to others available in the market.

APPENDIX III. ACRONYMS

ACN	Aménagements en courbes de niveau; aka, ridge tillage
AFNet	African Network
AMF	Arbuscular Mycorrhizal Fungi
BARI	Bangladesh Agricultural Research Institute
BBC	British Broadcasting Company
Bt	*Bacillus thuringiensis*
CARE	International non-governmental organization
CENTURY	General computer model of plant-soil nutrient cycling
CGIAR	Consultative Group on International Agriculture Research
CIAT	Centro Internacional de Agricultura Tropical
CIP	International Potato Center (Lima and Nairobi)
CIRAD	Centre International de Recherche en Agriculture pour le Developpment
Cryl	Class of Bt protein in maize toxic to lepidopteran
Cry3	Class of Bt protein in maize toxic to coleopteran
CRSP	Collaborative Research Support Program, USAID
DOA	Department of Agriculture
DSS	Decision Support System
DSSAT	Decision Support System for Agrotechnology Transfer
DST	Decision Support Tools
EEP	External Evaluation Panel
EGAT	Bureau for Economic Growth, Agriculture and Trade, USAID
ENEA	Ecole National de Economie Applique (Senegal)
FAO	Food and Agricultural Organization of the United Nations
FFS	Farmer Field School
GIS	Geographic Information Systems
GMO	Genetic Modified Organisms
GTZ	Deutsche Gesellschaft fur Technische Zusammenarbeit
HST	Healthy Seedlings Technology
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer project
ICM	Integrated Crop Management
ICRAF	World Agroforestry Center (Kenya)
ICRISAT	International Center for Research in the Semi-Arid Tropics
IDIAP	Instituto de Investigacion Agropecuaria de Panama (Panama)
IDRC	International Development Research Centre
IER	Institut d'Economie rurale, Mali
IFDC	International Fertilizer Development Center
IGP	Indo-Gangetic Plains
INTSORMIL	International Sorghum and Millet CRSP
IPM	Integrated Pest Management CRSP
IRI	International Research Institute
IRRI	International Rice Research Institute
ISFEIP	International Soil fertility Evaluation and Improvement Project
ISNM	Integrated Soil Nutrient Management
ISRA	Institut Senegalais de Recherche Agricole (Senegal)

KARI	Kenya Agricultural Research Institute (Kenya)
LEACHP	Leaching Estimation and Chemistry Model for Phosphorus
LEI	Institute of Agricultural Economics (Netherlands)
LGUs	Local government units
MAFF	Ministry of Agriculture, Forestry and Fisheries (Timor-Leste)
ME	Management Entity
MD	Minimum data
MDGs	Millennium Development Goals
MRI	Magnetic resonance imaging
MSU	Montana State University (USA)
NARS	National Agricultural Research Systems
NGO	Non-Government Organizations
NPK	Nitrogen, Phosphorus, Potassium
NuMaSS	Nutrient Management Support System
NUTMON	Nutrient Monitoring
PCR	Polymerase Chain Reaction
PDA	Personal Data Assistant
PIs	Principal Investigators
PRONAMACH	National Watershed Management and Soil Conservation Program (Peru)
QTL	Quantitative Trait Loci
RI	Genetic code
RDRS	Rangpur-Dinajpur Rural Service, (Bangladesh NGO)
RFLPs	Restriction Fragment Length Polymorphisms
SANREM	Sustainable Agriculture & Natural Resource Management CRSP
SARI	Savanna Agricultural Research Institute (Ghana)
SM CRSP	Soil Management Collaborative Research Support Program
SOM	Soil organic matter
SWC	Soil Water Conservation
TC	Technical Committee
TOA	Tradeoff Analysis
TSBF	Tropical Soil Biology and Fertility
UA	Makerere University (Uganda)
UC	University of California
WUR	Wageningen University and Research Center (Netherlands)
USAID	United States Agency for International Development
USG	United States Government
WEPP	Water Erosion Prediction Project
ZEF	Center for Development Research (Germany)

APPENDIX IV. SCHEDULE AND ITINERARY FOR EEP ON-SITE VISITS

December 15, 2005—SM CRSP

Planning Meeting of EEP members with USAID (David Hess, Jeff Brokaw, and Mike McGahuey) in Washington, D.C.

January 15 to 18, 2006—NuMaSS

Site visits in **Thailand** by Tom Walker (EEP), substituting for Ron Knapp and Gordon Tsuji (ME).
PI: Tasnee Attanandana (Kasetsart) and Russell Yost (Hawaii)
January 15—Arrive in Bangkok.
January 16—On-site review and meetings at the Suphan Buri Research Station.
January 17—Meetings at Kasetsart University.
January 18—Depart from Bangkok.

January 18 to 21, 2006—Rice-Wheat Technology Adoption/Carbon Sequestration

Site visits in **Bangladesh** by Eric Craswell (EEP), Gordon Tsuji (ME) and Bob Hedlund (USAID).
PI: *John Duxbury (Cornell) and Julie Lauren (Cornell)*
January 18—Meeting with USAID mission by Hedlund; Craswell and Tsuji arrive in Dhaka; drive to Rajshahi (4 hrs.).
January 19—Rajshahi to Durgapur (site visit in Alipur); to Rangpur.
January 20—Rangpur to Thakugaon and Dinajpur.
January 21—Depart Dinajpur for Dhaka (6 hours) to Manila via Singapore.

January 22 to 26, 2006—NuMaSS

Site visits in the **Philippines** by Craswell, Tsuji, Hedlund.
PI: *Madonna Casimero (PhilRice) and Russell Yost (Hawaii)*
January 22—Arrive in Manila, then to Munoz (Philippine Rice Research Institute).
January 23—Review sessions during annual meeting of collaborating national scientists at PhilRice.
January 24—Field visit to demonstrate soil identification methods and continuation of meetings/sessions.
January 25—Review session with participants at PhilRice.
January 26—Meeting with Daniel Moore and Oliver Agoncillo, USAID/Manila.

February 22 to 25, 2006—NuMaSS/ Carbon Sequestration

Site visits in **Mali** by Will Blackburn (EEP), and Mike McGahuey (USAID).
PI: Mamadou Doumbia (IER), Abou Berthe (IER), Russell Yost (Hawaii)
February 21—Arrive in Bamako.
February 22—On-site visit with meetings in Siguidolo.
February 23—Meetings with collaborators in Bamako.
February 24—Meet with USAID/Bamako.

February 26 to March 2, 2006—Carbon Sequestration/Tradeoff Analysis

Site visits in **Ghana** by Blackburn and James Tiedje (EEP), McGahuey and Tsuji.
PI: *James W. Jones (Florida) and John Antle (Montana State)*
February 26—Meeting with USAID mission and regional office staff in Accra.
February 27—Meetings and review sessions with Carbon Sequestration project lead by Florida and with the Tradeoff Analysis project lead by Montana State.
February 28—On-site visit and meetings at Kpeve.
March 01—Review session with collaborators in Accra.

April 19 to 22, 2006—NuMaSS

Site visits in **Honduras** by Blackburn, Knapp (EEP), Tsuji, Uehara (ME) and McGahuey (USAID).
PI: *T. Jot Smyth (North Carolina State)*
April 19—Arrival into Tegucigulpa.
April 20 and 21—Meetings and review sessions with collaborators from Panama, Nicaragua, Mexico and Honduras in Tegucigulpa.

May 11, 2006—Biotechnology

Site visit to **Cornell University** by Teidje (EEP).
PI: Medha Devare (Cornell) and Janice Thies (Cornell)
May 11—Meetings and review sessions with PIs in Ithaca.

May 25, 2006—Biotechnology

Site visit to the **University of Florida** by Teidje (EEP).
PI: *Eduardo Vallejos (Florida), Melanie Correll (Florida), James W. Jones (Florida)*
May 25—Meeting and review sessions with PIs in Gainesville.

June 27 to 30, 2006—SM CRSP

Site: Denver, Colorado. Meeting of PIs with EEP.
PI: *All PIs and John Havlin (Chair, SM CRSP Board of Directors)*
June 27 and 28—Presentations of project accomplishments and progress by PIs.
June 29 and 30—Completion of first draft of EEP report.

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