

Annual Progress Report
Decision Aids for Integrated Soil Nutrient Management
February 11, 1997 - February 10, 1998

Summary

During the first year of the project potential sites intensive testing areas in Costa Rica, Mali and Philippines were visited, selected and most of the baseline assessment surveys have been completed. Representatives from each of the intensive testing areas joined 15 of the 17 U.S. project-members for a 3-day workshop, wherein the 5-year project plan was discussed, evaluated and adjusted to fit the needs of the intensive testing areas. This marks the first time in project history when the entire team assembled in a single meeting. Core field experiments to evaluate decision support systems and acquire needed information at the testing areas were designed and are currently under consideration by collaborators at these sites. One of the immediate impacts of our site visits and baseline surveys was to provide a catalyst for information exchange among local groups. Integration of existing technical data and contact information among these groups will help create a stronger base for sustained development in these rural sectors.

The integrated soil nutrient management decision support system (IntDSS) has been designed on paper, discussed with all project members, revised, and programming the first prototype is underway using Delphi as the programming platform. The prototype contains modules for diagnosis of soil nutrient problems, prediction of corrective amendments and guidance for recommended lime and fertilizer use. Existing versions of the acidity, N and P decision support systems are being reprogrammed in Delphi by project members at three of the four participating U.S. universities for insertion as containers into the IntDSS prototype. Feedback received from our overseas partners was essential to the design and development of an interface that will work in multiple environments and cropping systems. One auxiliary tool to complement IntDSS in guidance on use of local lime sources was developed, and another to estimate nutrient input-export balances at the field and farm scale is under programming.

Investigations began to specifically address information gaps in acidity, N and P components of the DSS. These include development of predictions on Ca and Mg movement into acid subsoils; estimates of N mineralization and transfer coefficients under various combinations of soil, climate and crops; diagnosis and predictions for P use in tree crops; and improved predictions of soil P buffer coefficients. These investigations involve team efforts in literature surveys, and field/laboratory activities with overseas collaborators. During the year project team-members published or presented at meetings 26 papers related to knowledge assemble and information gaps in soil acidity, N and P management.

The project funded 36 individual travel events during the year. With the exception of the project's planning workshop all travel was to either Africa, Asia or Latin America. Conservative estimates of external funding to the project, primarily through contributions in kind, exceed \$371,000 during the first year.

Introduction

The goal of this project is to integrate and disseminate decision aid tools that will reduce soil acidity and nutrient limitations to food production and quality. The tools will facilitate the diagnosis of soil nutrient constraints and help the user to select appropriate management practices for location-specific conditions.

The 5-year plan for project tasks are organized into two major categories: *developmental research* and *outreach activities*. Developmental research includes tasks to do the following:

- merge the single-constraint decision support systems (DSS) for acidity, N and P into an integrated nutrient management system (IntDSS);
- synthesize, analyze and assemble knowledge required to overcome recognized information gaps in the existing information base for acidity, N and P;
- test and refine IntDSS; and
- develop auxiliary tools to facilitate use of the integrated knowledge base by a variety of users.

Outreach activities involve two major types of collaborative effort: *intensive testing areas* and an *extensive evaluation network*. Intensive testing areas are a representative region in each of three agroecological zones (semi-arid, wet-dry and humid tropics) where there is significant potential for tools developed by this project to alleviate soil acidity, N and P management problems. These three regions provide real life situations where all developmental research by the multi-disciplinary team of 16 scientists from four U.S. universities (Cornell, Hawaii, N.C. State and Texas A&M) will be conducted jointly with national and international institute collaborators. The extensive evaluation network focuses on the evaluation of products under a variety of user conditions, once suitable performance is achieved at the intensive testing areas. Although major efforts in product evaluation will occur towards the end of the 5-year project, early and continued contact with network collaborators will help ensure global relevance in product design and knowledge assembly.

The Management Entity has developed a new format for reporting progress and developing annual workplans that alters the organization of project tasks as outlined in the project proposal. Project tasks or activities are to be grouped according to the outputs or products to which they contribute; outputs and/or products are then grouped according to the stated project objective that they collectively will achieve. Progress reports, in this new format, are intended to reflect a starting point for the subsequent year's project workplan. Because of this close linkage between annual reports and the subsequent year's workplan, this report on project tasks and activities during the first year were structured according to the new format and the project's three stated objectives.

Objective 1: Develop an integrated computerized knowledge base for global use in diagnosing and recommending practical solutions to soil acidity and nutrient problems, which considers differences in resource availability and soil, climate, crop and management factors contributing to location-specific acidity and nutrient constraints.

Output 1 Integrated Decision Support System (IntDSS) Software - merge the three existing single-nutrient decision support system prototypes (ADSS, NDSS, and PDSS) into a functional, fully integrated soil nutrient management DSS.

The three existing DSS's were programmed under different languages with different formats and structures. In order to produce a fully functioning integrated program, each individual DSS must be reprogrammed, combined by a common interface and fully integrated with each other. This means that nutrient recommendations must account for interactions between N, P and lime, as well as cost and country infrastructure considerations. Milestone events towards development of IntDSS software, during the 5-year plan are as follows:

- initial IntDSS prototype developed in year 1 with each DSS reprogrammed into a common language, computer interface, and using a common database;
- intermediate IntDSS prototype releases in years 2 and 3 with improved analytical tools and/or algorithms for integration across nutrients; integration is tested by users and necessary refinements are identified; and
- final release of IntDSS in year 5.

Lead Investigators and Contributors:

Deanna Osmond (NCSU) coordinates the IntDSS software development effort, with inputs from Shaw Reid (NDSS), Jot Smyth (ADSS) and Russell Yost (PDSS) through their coordination roles for the individual DSS improvement tasks. Additional contributors to this output during year 1 are listed according to their respective institutions:

Cornell University - David Bouldin

University of Costa Rica - Alfredo Alvarado, Raphael Salas

University of Hawaii - Nguyen Hue, Mike Robotham, Richard Kablan, Xinmin Wang

Institut d'Economie Rurale (Mali) - Adama Coulibaly, Mamadou Doumbia

North Carolina State University - Fred Cox, Daniel Israel, Frank Smith, Michael Wagger, Arthur Wollum

PhilRice and IRRI (Philippines): Teodula Corton, Thomas George

Texas A&M University: Frank Hons, Anthony Juo

Progress:

1. A commercial programming software was selected to ensure an efficient user-computing environment. This involved making some long-range projections and basic decisions about minimum hardware requirements for computers that will run the final release of IntDSS software. The minimum configuration was defined as a computer with a Pentium chip and a CD-ROM. Two software programming languages were explored: Delphi and Visual Basic. The Delphi platform was selected based on greater power and programming flexibility.
2. Considerable time was initially devoted to evaluation of the user interface design, to minimize the need for future adjustments and reduce programming costs. Without an

“easy-to-use” interface, users will react negatively to a computer program and refuse to use it. The IntDSS interface was conceptually designed to include the following (Figure 1):

- “Containers” for each individual DSS to be programmed by individuals at three separate universities;
- Program modules for (a) diagnosis of soil nutrient problems, (b) prediction of corrective amendments and (c) guidance for recommended lime and fertilizer use; questions to be asked for obtaining information from users and order of the questions were determined for each module; and
- Two levels of help sub-programs for assistance to the user: programmatic and informational.

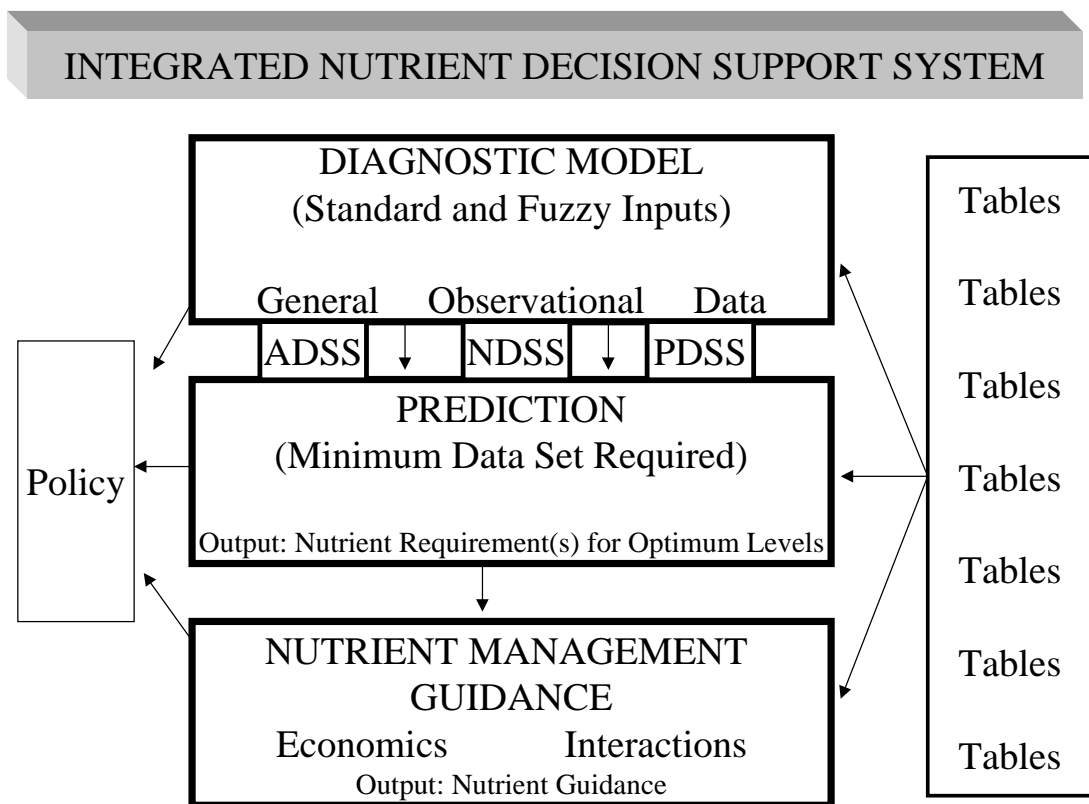


Figure 1. Linkages between modules, databases and individual decision support systems in the initial prototype of the Integrated Decision Support System (IntDSS).

3. Once major concepts for the program were determined, the interface was “paper-prototyped” - the interface was designed on paper and reviewers worked through the interface as if they were using a computer. The paper prototype was reviewed during the 3-day project planning workshop held at the University of Hawaii during December 1997

(Smyth, 1998). Workshop participants included representatives from the ME, 15 out of 17 project members for the four U.S. universities, and two representatives each from intensive testing sites in Costa Rica, Mali and Philippines. It was decided at the workshop to focus IntDSS knowledge assembly on the following crops: cassava, coffee, cowpea, maize, millet, peach palm, peanut, *Phaseolus* beans, potato, sorghum, soybean, sugar cane, upland rice and wheat. Workshop participants provided many excellent suggestions that were incorporated to the paper prototype.

4. All three individual DSS prototypes had to be reprogrammed in the Delphi environment. Reprogramming of ADSS was under NCSU's responsibility and is now completed. Reprogramming responsibilities for NDSS was with Cornell University and PDSS with University of Hawaii, but neither provided a report on the status of this activity.
5. One of the strengths of this project is that we are compiling data from numerous experiments conducted throughout the tropics on major agricultural crops. It is essential that collected data and information be assembled in IntDSS tables designed for maximum flexibility, speed and power. These data tables were designed, reviewed, redesigned, and are currently in their second review.
6. Templates for tables were designed in a spreadsheet format for use by project members and overseas collaborators in collection/assembly of pertinent agronomic and soils data from literature reviews, past SM-CRSP research and unpublished investigations. These data tables are currently being tested by selected users prior to their release to all individuals involved in information searches.
7. Since some portions of all IntDSS components (interface, data tables and individual reprogrammed DSS's) are available, programming of the IntDSS in Delphi has started.
8. This project involves 17 scientists distributed among four U.S. universities and numerous collaborators throughout the world. Effective communication is, therefore, an essential project activity. Considerable time was devoted to design and establishment of a project website to facilitate and promote coordination across the project. The website located at the following address: <http://intdss.soil.ncsu.edu/sm-crsp>. The site currently contains a full description of the project's 5-year plan, links to individual project-member and overseas collaborator websites (when available), addresses for contacting project coordinators, and calendar's for planned travel and project events. Website structure is in place to begin adding detailed information characterizing intensive testing areas and data which is beginning to be produced from ongoing activities. All project documents (reports on travel, workshops, surveys, and "white papers" are produced in Acrobat Reader file format (*.pdf), and these will soon be accessible for downloading from the website. During the 11 months since we began developing the website, it has been visited 368 times by 111 unique IP addresses from the Australia, Brazil, Canada, China, Costa Rica, Denmark, Germany, U.K. and U.S.

External Funding and Support

The feedback we have received from our overseas partners has been essential to design and development of an interface that will work in multiple environments and cropping systems. Significant time (and money) has been saved through their participation in the design phase of the IntDSS software.

Travel and Meetings Attended

Many of the details about the IntDSS design were finalized through discussions held among project team-members and overseas collaborators during site visits to Costa Rica, Mali and Philippines (Osmond et al., 1997ab; Reid et al., 1997). Approximately one-third of the program for the project planning workshop held in Hawaii (Smyth, 1998) focused on design, assembly and information needs for the IntDSS software. Program structure consisted of presentations in plenary session on various components of software design followed by small-group discussions with subsequent reports from each group and discussion of these reports by all workshop participants.

Relevant Publications, Reports and Presentations at Meetings

Osmond, D., S. Reid, M. Robotham, F. Smith, J. Smyth and R. Yost. 1997a. Report on trip to Costa Rica, July 13-19, 1997. USAID Grant No. LAG-G-00-97-00002-00. SM-CRSP IntDSS Project. 8p.

Osmond, D., S. Reid and R. Yost. 1997b. Report on trip to Philippines, August 13-21, 1997. USAID Grant No. LAG-G-00-97-00002-00. SM-CRSP IntDSS Project. 9p.

Reid, S., F. Smith, J. Smyth and R. Yost. 1997. Report on trip to Senegal and Mali, September 25 - October 1, 1997. USAID Grant No. LAG-G-00-97-00002-00. SM-CRSP IntDSS Project. 9p.

Smyth, T.J. 1998. Summary report of the program planning workshop: decision aids for integrated soil nutrient management project. Soil Management CRSP, 1-3 December 1997, Honolulu, HI. 55p.

Output 2 Field evaluation and refinement of IntDSS software - testing and refining the integrated decision support system under multiple environments and agricultural systems.

The process of developing the IntDSS software is a continuous feedback loop among developmental research and outreach activities. Upon the synthesis of existing knowledge the team gathers to formulate options and refine developmental research needs. Prototypes are tested, and the team of U.S. scientists and collaborators critique/discuss/improve the prototypes. With each repetition of this cycle the product approaches desirable performance.

IntDSS prototype testing and evaluation will initially focus on the intensive testing areas. Once decision support products and tools achieve suitable performance in intensive testing areas, they will be evaluated and tested under a variety of user conditions throughout the extensive evaluation network. Milestone events in field evaluation and refinement of IntDSS software, during the 5-year plan are as follows:

- team visits to Costa Rica, Mali and Philippines for selection of intensive testing sites in conjunction with host-country collaborators - year 1;
- baseline assessment of social, economic and cultural conditions, infrastructure, soil resources and nutrient management needs for each intensive testing site - year 1;
- refinement of the project's 5-year plan of research and outreach activities to ensure the particular nutrient constraints at each site are properly addressed - year 1;
- developmental field research and testing/evaluation of IntDSS at intensive testing sites - year 2 - 5

- project impact assessment surveys at intensive testing sites - years 3 and 5; and
- feedback on evaluation of IntDSS software and auxiliary tools from extensive evaluation network - years 2, 4 and 5.

Lead Investigators and Contributors

Coordination of activities at each intensive testing site was assigned to a project team-member at one of the U.S. universities. These coordinators are Jot Smyth (NCSU) for Costa Rica, Lloyd Hossner (TAMU) for Mali and Russell Yost (UH) for the Philippines. Collaborating institutions and primary contacts for each site are as follows:

Center for Agricultural Research/University of Costa Rica - Alfredo Alvarado and Raphael Salas
 Institute d’Economie Rurale, Mali - Mamadou Doumbia and Aminata Sidibe (Sotuba Station);
 Adama Coulibaly, Oumar Coulibaly, and Zoumana Kouyate (Cinzana Station)

Philippine Rice Research Institute/IRRI - Teodula Corton (Ilagan Experiment Station) and
 Thomas George (IRRI)

All the project’s U.S. team members contribute to intensive testing site activities through their individual tasks.

Progress

1. During initial months after project funds became available, teams of project members traveled to Costa Rica, Mali and Philippines to select intensive testing sites in conjunction with host-country collaborators. Travel events, U.S. team-members and host-country institutions are listed in Table 1. A separate report is available for each of these trips (Osmond et al., 1997ab; Reid et al., 1997).

Table 1. Travel events, dates, U.S. team-composition and host-country institutions participating in selection of the project’s intensive testing sites.

LOCATION	TRAVEL DATES	U.S. TEAM	HOST-COUNTRY INSTITUTION
Sarapiqui, Costa Rica	July 13-19, 1997	Osmond, Reid, Robotham, Smith, Smyth, Yost	Center for Agricultural Research/University of Costa Rica (UCR)
Cagayan, Luzon, Philippines	August 13-21, 1997	Osmond, Reid, Yost	Philippine Rice Research Institute (PhilRice)/International Rice Research Institute (IRRI)
Cinzana, Mali	September 25 - October 1, 1997	Reid, Smith, Smyth, Yost	Institute d’Economie Rurale (IER)

These areas were selected based on a combination of criteria:

- representation of major ecosystems in the tropics, as well as different social, political, economic and cultural conditions where our products will be used;

- soil and climate conditions suitable for conducting the developmental research to fill existing knowledge gaps in the decision support systems; and
- accessible with good on-site institutional capacity of collaborators.

The selected sites provide a variety of social, economic and cultural conditions where soil acidity, N and P limit crop production and quality (Table 2).

Table 2. Rainfall, soil, cropping system characteristics and nutrient constraints of the project's intensive testing areas.

TESTING SITE	ANNUAL RAINFALL	DOMINANT SOILS	CROPPING SYSTEM	NUTRIENT CONSTRAINTS
	mm			
Costa Rica	3,520	Andisols/Ultisols	heart-of-palm from peach palm	acidity, N & P
Mali	600	Alfisols	millet-cowpea intercrop	acidity, N & P
Philippines	1,500-2,000	Ultisols/Oxisols	upland rice	acidity, N & P

2. Baseline assessment surveys of the Costa Rica and Mali sites were completed in early March under the direct coordination of Frank Smith. Lloyd Hossner and Frank Hons (TAMU) also participated in the survey of the Mali site. Through interviews with farmers, agro-industry and government personnel the surveys provide a diagnosis of current conditions at the testing sites and the kinds of information and methods which decision makers use to identify problems and choose solutions. The studies provide feedback that can help guide the research and development programs, as well as a benchmark for future evaluation of decision processes and results. Participatory rural appraisals were conducted within each region, with a focus on farm systems, decision making and coordination of on- and off-farm activities. Survey design was based on feedback from participants of the Hawaii project-workshop (Smyth, 1998) as to the kinds of information needed to build and evaluate the IntDSS system. Final versions of the survey instrument were developed with on-site collaborators in a language comfortable to the local population. There were a total of 38 farmers interviewed at the site in Costa Rica and 55 in Mali. A detailed draft report has been prepared for each site survey. The final reports will be ready for distribution in April. Baseline survey of the Philippine site is ongoing, under the coordination of Russell Yost, PhilRice and IRRI collaborators. One of the immediate impacts of our project's site visits and baseline surveys was to provide a catalyst for information exchange among local groups about issues of common interest and opportunities for on-site collaboration. Integration of existing technical data and contact information among these groups will help create a stronger base for sustained development of the rural sector.

3. A major objective of the workshop held at the Univ. of Hawaii in December 1997 was to jointly refine our project's 5-year plan of research and outreach activities to ensure the nutrient constraints at each site were properly addressed. The workshop was the first opportunity in all project history (pre-proposal, proposal, and early implementation) for all members to convene for a joint meeting. Host-country representatives presented detailed characterizations of each intensive testing area. Small-group discussions enable participants to identify knowledge gaps and information needs on soil acidity, N and P management for each intensive testing area. The complete reports on each testing area and outcomes of the group discussions are included in the workshop report (Smyth, 1998).
4. Since December project coordinators (Osmond, Reid, Smyth and Yost) have been designing field trials for each testing area, based on outcomes of workshop discussions and in consultation with intensive testing site collaborators. One of the objectives for Lloyd Hossner and Frank Hons' travel to Mali was to finalize workplans for field trials in the Cinzana area. Full details of these field activities will be provided in workplans for the project's second year.

External Funding and Support

- The University of Hawaii provided conference facilities for the project workshop at no cost to the project;
- Baseline assessment surveys involved full-time contributions of host-country teams with 10-12 members for three days at no charge to the project.

Travel and Meetings Attended

- Site selection visits to Costa Rica, Mali and Philippines (see Table 1);
- Project Planning Workshop, 1-3 December 1997, University of Hawaii, Honolulu, HI - project funded travel for 2 participants each from Costa Rica, Mali, and Philippines, 2 from Cornell University, 7 from N.C. State University and 2 from Texas A&M University.
- Lloyd Hossner and Anthony Juo - visit to IntDSS and Steeplands project sites in Costa Rica; explore potential collaborative activities with University of Managua and National Agricultural Institute in Nicaragua; 11-22 January 1998.
- Frank Smith - travel to Costa Rica for baseline assessment survey; 29 January - 7 February, 1998.
- Frank Smith - travel to Mali for baseline assessment survey; 22 February - 4 March, 1998.
- Lloyd Hossner and Frank Hons - travel to Mali for baseline assessment survey and finalization of project workplans in the Cinzana area; 22 February - 1 March, 1998.

Relevant Publications, Reports and Presentations at Meetings

Osmond, D., S. Reid, M. Robotham, F. Smith, J. Smyth and R. Yost. 1997a. Report on trip to Costa Rica, July 13-19, 1997. USAID Grant No. LAG-G-00-97-00002-00. SM-CRSP IntDSS Project. 8p.

Osmond, D., S. Reid and R. Yost. 1997b. Report on trip to Philippines, August 13-21, 1997. USAID Grant No. LAG-G-00-97-00002-00. SM-CRSP IntDSS Project. 9p.

Reid, S., F. Smith, J. Smyth and R. Yost. 1997. Report on trip to Senegal and Mali, September 25 - October 1, 1997. USAID Grant No. LAG-G-00-97-00002-00. SM-CRSP IntDSS Project. 9p.

Smyth, T.J. 1998. Summary report of the program planning workshop: decision aids for integrated soil nutrient management project. Soil Management CRSP, 1-3 December 1997, Honolulu, HI. 55p.

Objective 2: Improve the diagnosis and recommendations for acidity and nutrient problems by identifying and resolving knowledge gaps through extensive literature reviews and, when necessary, developmental research.

Output 1 Enhancing the knowledge base for the acidity decision support system - collecting, developing and synthesizing soil, plant and management information to improve the diagnosis and recommendations of location-specific problems related to the soil acidity syndrome.

The current ADSS knowledge base does not predict the rate of movement of basic cations into acid subsoils from surface-applied liming materials. This limits our ability to recommend management strategies for alleviating acidity constraints below the depth of lime incorporation, or properly accounting for the economic value of improved crop rooting depth as lime reaction products move into the subsoil. The introduction and movement of Ca and Mg into subsoils is a major consideration for sustained productive use of the acid, sandy soils in the African Sahel. The acidity knowledge base needs to be expanded to evaluate soil conditions with limited Ca and/or excess Mn. The consequences of using lime materials low in Mg on soil Mg availability also need to be added to the ADSS knowledge base.

All activities for improving the ADSS knowledge base are scheduled for completion by the end of the year 3. Investigations related to basic cation (lime) movement began in year 1 and continue through year 2. Investigations related to Ca and Mg deficiencies and/or Mn toxicity are scheduled for years 2 and 3.

Lead Investigators and Contributors

Jot Smyth provides overall coordination to activities related to ADSS. Investigations on basic cation movement were initiated this year under the direction of David Bouldin (Cornell) and Anthony Juo (Texas A&M). Additional contributors to this output during year 1 are listed according to their respective institutions:

Organization of Tropical Studies/Costa Rica - Eugenio Gonzales and Orlando Vargas

University of Costa Rica/Costa Rica - Alfredo Alvarado

Institut d'Economie Rurale/Mali - Mamdou Doumbia (Sotuba Station); Zoumana Kouyate and Adama Coulibaly (Cinzana Station)

Texas A&M University - Rick Wesch, project assistant

Progress

1. Investigations on movement of lime-reaction products require time and detailed soil measurements. Initial efforts, therefore, concentrated on review of existing available data from Brazil, Colombia, Costa Rica, Puerto Rico and New York. In each case relations were developed between soil pH and both (a) the sum of exchangeable Al, Ca and Mg, and (b) exchangeable Al. These relations describe soil Ca-Mg-Al relationships in acid

soils as a function of pH. The data sets provided linear changes in exchangeable cations with changes in soil pH - exchangeable Ca+Mg+Al increased and exchangeable Al decreased with increasing soil pH. The hypothesis was that exchangeable cations would follow these trends during soil acidification, and any loss of cations through leaching was accompanied by an equivalent charge loss of anions. Investigations into field cropping systems associated with the soil data sets indicated that NO_3 and HCO_3 were the primary anions associated with cation movement. In some cases total NO_3 loss exceeded equivalent charge loss in Ca+Mg, suggesting possible movement of Al and dissolution of Al compounds.

2. Relations were also developed on the same soil data sets for ratios of Al/(Ca+Mg) in both the soil solution and exchange complex. Relationships between the solution and exchangeable ion ratios were linear, suggesting that knowledge of exchangeable soil cation composition would allow prediction of solution cation composition and, presumably, Ca+Mg composition of the solution. Combination of these relationship with pH-exchangeable Al relations (described in item 1) could help elucidate the role of dissolution of Al compounds in soils with pH below 5.2. A major challenge in estimating Ca and Mg movement lies in the estimation of soil N mineralization, which is also relevant to information needs of the N decision support system.
3. Review of these existing soil data sets provides guideline criteria on the soil analytical data which investigators for this output will begin to collect through surveys of literature unpublished research, contacts with collaborators and planned field experiments at the intensive testing sites.
4. A field experiment at the Cinzana, Mali intensive testing site was modified to initiate characterization of Ca and Mg movement in acidified Alfisols. The experiment is conducted on two soil types: a sandy soil on the upper slope position and a loamy soil at the footslope. Treatments consist of tillage for conventional ridging and tied ridging; continuous millet versus a millet/cowpea rotation on the sandy soil and continuous sorghum versus a sorghum/cowpea rotation on the loamy soil. Simple drainage lysimeters will be installed in the field to monitor leaching losses. These data will be complimented by leaching studies in the laboratory using undisturbed soil columns.
5. Research on Ca distribution and movement in perudic Ultisols under both natural and agroforestry systems was initiated in La Selva Station, Costa Rica in conjunction with the Organization of Tropical Studies.
6. Discussions by the soil acidity group (Bouldin, Corton, Coulibaly, Hue, Juo, Kablan, Salas and Smyth), during the project planning workshop (Smyth, 1998), helped clarify strategies to obtain and structure information needed for ADSS. The group survey of literature will focus on multiple acidity factors: Al and Mn toxicity, Ca and Mg deficiency, lime movement and organic amendment effects. We need to better quantify the % soil Al saturation for obtaining 95% of maximum yield for the targeted crops in IntDSS. Essential information for assessing transferability of existing research data include lime source and analysis, soil exchangeable data at one or more sampling dates after liming, and rainfall. Desirable auxiliary information include experiment

management practices, details on soil analytical methods, soil chemical data with profile depth for several times after liming, and crop yields.

External Funding and Support

- IER/Mali - senior and technical staff time, vehicle, farm, laboratory and computing facilities contributed are estimated as \$10,000;
- OTS/Costa Rica - senior and technical staff time, vehicle, farm, laboratory and computing facilities contributed are estimated as \$6,000; Peace Corp fellowship awarded to project assistant in the amount of \$25,000.

Travel and Meetings Attended

- Lloyd Hossner and Anthony Juo - travel to Costa Rica to initiate collaborative research with OTS at La Selva Station; 11-22 January 1998.

Relevant Publications, Reports and Presentations at Meetings

- Cravo, M.S. and T.J. Smyth. 1998. Soil fertility management for sustainable cropping on an Oxisol in the Central Amazon. *Rev. Bras. Ci. Solo* 21:607-616.
- Dierolf, T.S, L.M. Arya, and R.S. Yost. 1997. Water and cation movement in an Indonesian Ultisol. *Agron. J.* 89:572-579.
- Hossner, L. and A. Juo. 1998. Report on trip to Costa Rica, January 11-17, 1998. USAID Grant No. LAG-G-00-97-00002-00. SM-CRSP IntDSS Project. 2p.
- Hunter, D.J., L.G. Yapa, and N.V. Hue. 1997. Effects of green manure and coral lime on corn growth and chemical properties of an acid Oxisol in Western Samoa. *Biol. Fert. Soils* 24:266-273.
- Jallah, J.K. and T.J. Smyth. 1998. Assessment of rhizotoxic aluminum in soil solutions by computer and chromogenic speciation. *Commun. Soil Sci. Plant Anal.* 29:37-50.
- Li, M.B., N.V. Hue, and S.K. Hussain. 1997. Changes of metal forms by organic amendments to Hawaii soils. *Commun. Soil Sci. Plant Anal.* 28:281-394.
- Sanzonowicz, C., T.J. Smyth and D.W. Israel. 1998. Hydrogen and aluminum inhibition of soybean root extension from limed soil into acid subsurface solutions. *J. Plant Nutr.* 21:387-403.
- Smyth, T.J. 1998. Summary report of the program planning workshop: decision aids for integrated soil nutrient management project. Soil Management CRSP, 1-3 December 1997, Honolulu, HI. 55p.

Output 2 Enhancing the knowledge base for the N decision support system - collecting, developing and synthesizing soil, plant and management information to improve the diagnosis and recommendations of location-specific N problems.

Diagnosis and recommendations for N are based on N content of total above ground dry matter production for the targeted crop yield. Fertilizer N requirements are based on the differences between total above ground N needs and the N supplied by soil, manures and atmosphere. Unlike acidity and P, there is no single measure of soil N that allows an evaluation of N source efficiencies and mineralization transfer coefficients among different soils and climates. Coefficients must, therefore, be derived for a variety of soil, crop and climate conditions using prior experimentation whenever possible. Given the size of this task, acquisition and refinement of coefficients will be an ongoing process throughout the entire project. Transfer

coefficients for contributions of biologically fixed N need to be categorized in terms of a variety of factors: the legume source and its nutrient requirements, inoculant availability, C constituents, plant age, soil conditions, and timing and method of incorporation. Nitrogen losses need to be either incorporated into transfer coefficients or predicted.

Milestone events for this output, during the 5-year plan are as follows:

- annual improvement of the database on N transfer and mineralization coefficients to encompass a broader combination of soil, crop and climate conditions;
- prediction of N losses - year 3; and
- guidance for legume management and prediction of BNF contributions - year 5.

Lead Investigators and Contributors

Shaw Reid provides overall coordination to activities related to NDSS. During the past year Frank Hons and Shaw Reid received funding to begin the collection and calibration of N transfer and mineralization coefficients. However, all other U.S. members of the N group (Israel, Osmond, Waggoner and Wollum) and testing site collaborators participated in workshop discussions and have begun to share via correspondence their findings upon searches of the existing literature. Overseas collaborators contributing to this output during year 1 are listed according to their respective institutions:

Center for Agricultural Research/University of Costa Rica - Alfredo Alvarado and Raphael Salas

Institute d'Economie Rurale/Mali - Mamadou Doumbia and Aminata Sidibe (Sotuba Station);

Adama Coulibaly and Zoumana Kouyate (Cinzana Station)

International Rice Research Institute - Thomas George

Philippine Rice Research Institute - Teodula Corton

Progress

1. Data to calibrate NDSS for many climate, soil and crop conditions are often available in the literature. After the three intensive testing areas were selected, literature was searched to find N response data on some of the crops that have been chosen for inclusion in the decision support system - namely heart-of-palm, millet and upland rice. There was almost no data available on heart-of-palm, but many publications were available on millet and rice. There is more data available on flooded than upland rice and it is not yet known how transferrable this information would be between rice systems. However, few of the publications provided fertilizer N response data in sufficient detail for the calculations of N efficiency, residual soil N, and internal N requirements of the crop. We are confident that much of the required data is available, albeit in the "gray literature (i.e., locally available but not published in publications such as those of the USDA National Agricultural Library. Limited searches were also performed on green manures for Mali and Philippines.
2. Some important questions/findings were drawn from testings site visits, workshop discussions and literature examination:
 - a. Farmers in the Cinzana region of Mali use crop residues efficiently, but there are various losses of N during the year. In other areas of the Sahel, this N loss has been estimated as 35 - 50 kg N ha⁻¹ year⁻¹ and is equivalent to the N released annually by 1% organic matter. This N is not being replaced and potential productivity is being lost. Questions to be answered are how much of the N loss

- can be prevented and can organic matter be replenished by a more efficient N management scheme.
- b. Crop residues in Cinzana are composted in open pits after crop harvest. Nitrogen losses from pits, either by volatilization or leaching, have not been quantified. Composts are often applied to the field surface weeks or months before planting the next crop. Nitrogen losses prior to planting and crop uptake have not been quantified.
 - c. Little emphasis has been placed on upland rice production research, relative to irrigated systems, in the Philippines. This is because much of the area is under irrigated rice. Upland rice is often grown where other crops are at risk, either because of limited water or inputs necessary for successful crop production.
 - d. Upland rice is grown in the Philippines in rotation with a number of other crops, with may provide N residues for the rice crop.
3. During travel to Mali, Frank Hons made arrangements with Zoumana Kouyate to begin sampling a long-term sorghum/legume rotation experiment to determine seasonal variation in the timing and quantity of soil N and P mineralization among different legumes. This information will be used to assess the potential for NO₃ contamination of groundwater. The Soil-Plant-Water Analysis Laboratory at Sotuba Station has problems determining NH₄ and NO₃ due to lack of equipment. Frank Hons and Texas A&M technicians have been adapting microdiffusion techniques on-campus as a low cost substitute method for the Mali lab.

External Funding and Support

Time and resource contributions by Malian collaborators are allowing much more research to be conducted than the limited funding by this project. Senior and technical staff time, vehicle, farm labor and facilities contributions were equivalent to at least \$10,000.

Travel and Meetings Attended

- Lloyd Hossner and Frank Hons - travel to Mali to formalize workplans with collaborators from IER's Sotuba and Cinzana Stations; 22 February - March 1, 1998.

Relevant Publications, Reports and Presentations at Meetings

Zaongo, C., C. Wendt, R. Lascano, and A. Juo. 1997. Interactions of water, mulch and nitrogen on sorghum in an Entisol in the Sahel. *Plant Soil* 197:119-126.

Output 3 Enhancing the knowledge base for the phosphorus decision support system - collecting, developing and synthesizing soil, plant and management information to improve the diagnosis and recommendations of location-specific P problems.

PDSS is at a younger stage of development than the modules for acidity and N. For many conditions, predicted P requirements are uncertain or undetermined; existing coefficients need to be improved and expanded over more soil and crop conditions; our current ability to diagnose and prescribe P requirements for tree species is limited. Rock phosphate exists in local deposits and, when of high quality and applied to acid soils or perennial crops, it can be as effective as soluble fertilizer P. To enable users to consider rock P options algorithms are needed that predict their performance based on data and information available to the intended users.

Milestone events for this output, during the 5-year plan are as follows:

- Development of P diagnosis, prediction and fertilizer guidance for tree crops - beginning in year 1 and completed in year 3;
- Refinement of soil P coefficients for improved P predictions - beginning in year 2 and completed in year 3;
- Predicting effects of P fertilizer placement - year 3; and
- Prediction and fertilizer guidance for rock P use - beginning in year 4 and completed in year 5.

Lead Investigators and Contributors

Russell Yost provides overall coordination to activities related to PDSS. During the past year Yost received funding to begin the P activities related to tree crops. However, all but one of the other U.S. members of the P group (Cox and Hossner) and testing site collaborators participated in workshop discussions and have begun to share via correspondence their findings upon searches of the existing literature. Overseas collaborators contributing to this output during year 1 are listed according to their respective institutions:

University of Costa Rica - Alfredo Alvarado

Institute d'Economie Rurale/Mali - Mamadou Doumbia (Sotuba Station

International Rice Research Institute - Thomas George

Philippines Rice Research Institute - Teodula Corton

Federal University of Viçosa/Brazil - Roberto Novais

Federal University of Ceara/Brazil - Bonerges Aquino

EMBRAPA/Brazil - Lafayette Sobral

Progress

1. Diagnosis/Prediction/Guidance for Tree Crops -Position descriptions have been written and personnel selection is underway. Some current literature has been identified and will be the basis for consideration of coefficients for the estimation of P requirements for establishment phase of the tree crops and requirements for the diagnostic phase both during the juvenile and the mature phases.
2. Precision of P prediction methods - A method was developed and published that provides estimates of the precision associated with fertilizer predictions (Chen et al., 1997). This procedure illustrates that there is a great deal of variance in fertilizer P predictions and further identifies the factors that contribute the most to overall error. For example, the results indicate that variation in both the buffer coefficient and P critical level are the major sources of error. This suggests, in turn, that these two factors should be considered as the focus of research efforts to improve prediction. This result has been the basis for further work on improving the prediction of these coefficients described below.
3. Improved estimates of buffer coefficients - Initial estimates of buffer coefficients already implemented in the PDSS (Phosphorus Decision Support System) are based on the work of Cox (1994). Based on the work of Chen et al. (1997), we tried to improve the prediction of buffer coefficients in those soils where predictions were particularly unsatisfactory -- in soils with clay percentages greater than 50 (Wang, 1997). One of the characteristics of highly weathered soils is the high content of iron and aluminum oxides, which contribute to the usual high degree of aggregation of these soils. The effects of the

high degree of aggregation are to reduce the sorption of P to the outer surfaces of the aggregates (Linquist et al., 1997). While aggregation clearly influences the amounts of extractable P removed by plants, it was unclear whether these processes affected P sorption and extractability of added P and ultimately the estimation of P buffer coefficients.

A group of 10 soils varying in P sorption from 80 to 3300 mg P kg⁻¹ were analyzed for aggregate stability using standard methods of estimating geometric mean diameter. The depth of P entry into the aggregate was also estimated. These estimates were then used to predict measured buffer coefficients for comparison with the original method of clay percentage only (Cox, 1994). The results illustrated that the variance of the predicted buffer coefficient was reduced from 0.1025 to 0.039 indicating a substantial improvement in prediction precision (Wang et al., 1998).

4. Effects of aggregation -

a. *Field studies.* We examined soil aggregation patterns and the influence of aggregation on short-term extractable P on three upland soils in Southeast Asia (Matalom, Leyte, Philippines; Siniloan, Laguna, Philippines and Sitiung, Sumatra, Indonesia). The soils are tentatively classified as Typic Kandudult (Matalom), Typic Palehumult (Siniloan) and Typic Hapludox (Sitiung). Soil samples from four to five P regimes in the LTPE (Long-term phosphorus experiments) collected 30 days after the first P application were used for the study. Soil samples air-dried as collected from the plots were passed through a 4 mm sieve and then separated into aggregate size ranges of >2.0 mm, 2.0-1.0 mm, 1.0-0.5 mm, 0.5-0.25 mm and <0.25 mm using the dry sieving method. Soil aggregates larger than 4 mm were gently ground to pass through the 4 mm sieve. The weight of the soil fraction under the different aggregate ranges were determined. Each aggregate size fraction was analyzed for extractable P using the double acid extractant (Mehlich 1). The extractable P in each aggregate fraction as a proportion of total extractable P in the whole sample was also calculated.

Soils differed in their aggregation pattern. Matalom soil was less aggregated with 30% of the total soil weight consisting of aggregates of size <0.25 mm and with larger aggregates contributing proportionately less to the total soil weight. In contrast, the soil from Siniloan and Sitiung were more aggregated with 35% of the soil weight made up of aggregates larger than 2.0 mm.

Both soil aggregate size and applied P significantly ($P < 0.01$) influenced extracted P. In all three soils, the extractable P decreased significantly with increasing aggregate size. Extracted P was linearly related to applied P. Within each P level, the smaller the aggregate, the greater was the amount of extracted P per unit weight of soil. Smaller aggregate size results in greater reactive surface and, therefore, potentially could adsorb more of the applied P per unit weight than a larger aggregate size. The interaction between applied P levels and aggregate size was highly significant with extracted P increasing in greater degree with decreasing aggregate size. Thus, it is likely that P application in less aggregated

soils would result in high soil P adsorption or fixation compared to application in well-aggregated soils.

The highest P content in the smallest aggregate did not, however, always lead to the highest proportion of total extracted P in the smallest aggregate fraction as the soils differed in aggregation patterns. Thus, in the Matalom soil, 58% of the total extracted P was found in the smallest (<0.25 mm) aggregate size fraction due to both a predominance of this aggregate size in the soil and its high P content. In contrast, in Siniloan and Sitiung soils, the total extracted P tended to be more evenly distributed among the small and large aggregate size fractions.

These results confirm and extend earlier reports on a Hawaiian Ultisol indicating the importance of soil aggregation as a factor controlling P dynamics (Linguist et al., 1997). Although, we used a dry sieving method which is less precise in discriminating stable aggregates as compared to wet sieving, the marked differences observed between the soils indicate that all upland tropical soils cannot be treated the same for plant availability of immobile nutrients such as P. Again, such differences in aggregation pattern would not have been evident if the whole samples were ground to pass through a 2 mm sieve as ordinarily done for soil analyses. If aggregation has a major role in determining P availability to crops, it is imperative that soil P test procedures be adapted/developed to account for aggregate effects.

- b. *Laboratory studies.* Three soils, representative of soils of the humid tropics, were selected to determine the effects of aggregation on P sorption and on the estimation of P buffer coefficients. The soils included an Ultisol of a similar soil family as the soil used in Linguist et al. (1997) but developed on different soil materials, and two Oxisols, both with extremely high P sorption potential but varying in their aggregation status (Wang, 1997). The Ultisol, Leilehua, was highly aggregated as indicated by the geometric mean diameter (GMD) and exhibited substantially higher extractable P from the smaller aggregates, much as shown by Linguist et al., 1997. The Kapaa soil, one of the two Oxisols, also demonstrated the same increases in extractable P with smaller aggregates although this soil had not received fertilizer P for more than 5 years. This indicated that the higher extractable P in smaller aggregates persisted well after the rapid, initial sorption of P. The other Oxisol, the Wahiawa series, did not display the increased extractable P from smaller aggregates. Extractable P was roughly the same for all aggregate sizes. The structure of this Oxisol was, however, considerably different from that of the Kapaa soil. Wahiawa aggregates crumbled easily between the fingers while those of the Kapaa soil were very strong and broke only with difficulty. The difference in structure was also apparent in the GMD measurements, which differed significantly between the two soils. These results indicated that not all of the highly weathered soils display the aggregate effect on extractable P and that the geometric mean diameter may be useful to predict which soils will display this effect.

- c. *Greenhouse studies.* Based on the results of the studies of Linnquist et al. (1997) and Wang (1997) and later field studies in the Philippines and Indonesia (Magbanua and Thomas, 1997) there appeared to be many of the highly weathered soils in which extractable P increased with decreasing aggregate size. It was not clear whether these increases in extractable P also correspond to increased availability as measured by plants. Consequently, a study was undertaken to determine if the increases in extractable also resulted in improved availability and P supply.

Two crops were selected for the study -- lettuce and soybean. These two crops were grown on aggregate size fractions of the Leilehua soil studied by Wang (1997). The different-sized aggregates were mixed with crushed basalt to minimize differences in water relations and impedance to root growth. The results indicated that both growth and P uptake were significantly greater on soils with the higher level of extractable P.

Taken together the field, laboratory and greenhouse studies suggest that aggregation can affect P availability and probably should be considered in estimating soil reactivity with added P. Subsequent studies are needed to estimate the effects of this factor on the estimation and prediction of P buffer coefficients. This may be one factor that has contributed to the high variance and uncertainty in predicted buffer coefficients suggested in the work of Chen et al. (1997).

5. Improved estimates of short-term soil reactivity with P (P buffer coefficients) - Rapid laboratory incubation methods of estimating P reactivity of soils are key to predicting P availability both to improve predictions based on other soil characteristics and when other soil characteristics are missing but simple laboratory facilities are present. The P buffer coefficients are currently estimated from the clay content of the soil (Cox, 1994). However, a direct measure should be more accurate over a wider range of soil conditions. To investigate utilization of a direct measure of the P buffer coefficient, rates of P were added to sets of 6 to 13 kaolinitic soils from several U.S. Taxonomy orders and the mixtures were incubated either with or without drying cycles for periods of 16 h, 7 d (short-term with one drying cycle), or 5 months (long-term with numerous drying cycles). The 16-h treatments were dried overnight at 40°C, while the 7-d and 5-month treatments were air dried at room temperature. The samples were then extracted with the Mehlich-3 solution. Field crops had been grown on 10 of these soils for 5 to 7 yr after an initial application of 4 or 5 rates of P and Mehlich-3 P was measured annually. The following relationships were found:
- Mehlich-3 P increased linearly with rate of applied P, so two points would be sufficient to calculate the increase in Mehlich-3 P per unit of applied P. We have termed this increase the 'Mehlich-3 buffer coefficient' (M3BC);
 - M3BC decreased exponentially with time in the laboratory. Phosphorus fixation is very rapid initially, but slow markedly with time. This decrease has also been measured under field conditions;
 - Drying also decreased M3BC, but primarily on coarser textured soils. Drying may hasten P fixation and more closely approximate the soil test P after longer periods;

- d. Two sets of M3BC values were compared with predictions of field M3BC one year after P was applied. Field M3BC was related linearly to 5-month M3BC and quadratically to 7-d and 16-h M3BC.

It was concluded that for routine soil testing labs using the Mehlich-3 extractant, a 16-h (overnight), dried determination of M3BC would provide timely information on the P buffering capacity of the soil. With this knowledge, more accurate fertilizer recommendations may be made to raise the soil test P level to a specified amount. Field experiments have been conducted in Mali and are presently being analyzed that will be used to compare short term predictions of buffer coefficients with predictions of buffer coefficients based on soil characteristics. Attempts to predict buffer coefficients on these soils are not available to our knowledge, and the results would be a first step in improving P availability in view of the extreme scarcity of soil testing facilities for both research, extension, and for farmer samples. This represents an adjustment in the recommendation methodology that, in the U.S., has depended solely on soil testing to gauge soil P recommendations. It is clear that this methodology is not appropriate for the majority of the tropics where there is virtually no access to soil tests.

Laboratory methods of estimating P buffer coefficients will be compared with field-based estimates of P buffer coefficients from the experiments in Mali and the Philippines and Indonesia. This will complement existing data for Ultisols and Oxisols from Brazil and North Carolina.

6. During a one-year sabbatical at NC State University by Roberto Novais from Brazil knowledge related to the diagnosis and management of phosphorus problems among the different ecosystems in Brazilian agriculture was reviewed and synthesized into a 400-page draft of a book which will be published next year. This compilation of predominantly “grey literature” helps alleviate recognized knowledge gaps in the existing information base for soil phosphorus management and is transferrable to regions of Africa and Asia.
7. Phosphate rock - Literature search has begun and major factors associated with prediction of usefulness of P in rock phosphate is being determined. Preliminary factors may include the following:

Soil characteristics

1. Cation exchange capacity
2. Calcium saturation
3. Soil pH
4. Moisture content
5. P buffering capacity.

Rock phosphate

1. Carbonate substitution
2. Porosity

Crop characteristics

1. Ca requirement
2. Exudation of citric, malic, and oxalic acids.

3. Root morphology (particularly fineness)
4. Root/shoot ratio

External Funding and Support

- IRRI through its Upland Rice Research Consortium established the long-term P experiments and is providing continued support in terms of facilities, support staff and funds. The annual contribution is estimated to be in excess of \$100,000;
- The Brazilian government provided full sponsorship of the three Brazilian scientists who worked on PDSS-related issues during their sabbaticals at N.C. State University. The contribution in salaries, travel, housing allowance, and medical insurance is estimated to be in excess of \$180,000.

Travel and Meetings Attended

- Russell Yost to the International Fertilizer Development Center - to discuss issues related to phosphate rock use and management with Drs. D. Hellums, N. Chien, J. Henao, C. Baanante and A. Roy; February 1998.

Relevant Publications, Reports and Presentations at Meetings

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Objective 3 Develop auxiliary tools to the integrated knowledge base to enable local agriculturalists to diagnose and solve soil acidity and nutrient problems that predominate within the social, economic and agronomic characteristics of their regional domains

Output 1 Extensive evaluation network - evaluation of products and capturing knowledge under a variety of location-specific conditions

Within this group we envisage a) individuals with knowledge that should be incorporated into products. b) individuals with field and laboratory data sets that could be used to evaluate products for location-specific conditions, and c) established networks who would be interested and benefit from using our products in their programs. Milestones in activities related to this task

are project meetings to be held in years 1, 2, 4 and 5. Participants would be asked to consider relevance of planned tools to their local needs and suggest potential modifications or additions. In later years we would focus on obtaining feedback on evaluations of IntDSS and auxiliary tools when applied to their local conditions.

Lead Investigators and Contributors

Deanna Osmond provides overall coordination to activities related to the network, but all U.S. project team members participate as they travel overseas and interact with network members. Collaborators from the following institutions (countries/regions) have agreed to participate in the network, contribute their nutrient management knowledge base and evaluate the decision support software prototypes and auxiliary tools under their location specific conditions:

IBSRAM Steepland Network (Asia)

IRRI Rice Consortium (Asia)

CIMMYT Regional Maize Program (Central America)

Potash&Phosphate Institute Andean Program (Central-Latin America)

IBTA (Bolivia)

EMBRAPA (Brazil)

University of Viçosa (Brazil)

ISRA (Senegal)

Progress

1. Original plans were to include selected members of the extensive evaluation network to the project's planning workshop held at the University of Hawaii in December 1997. However, the budget cut on the project of \$83,333 in year 1 eliminated funds to support their travel and per diem.
2. Auxiliary tools for IntDSS -
 - a. Investigators at the University of Hawaii developed a computer spreadsheet for selection of liming materials and applied it successfully to decision-making scenarios in Indonesia. The decision aid tool optimizes selection from locally-available liming materials and determines the correct proportion of these materials while considering a variety of constraints such as quantity, cost, quality, depth of incorporation and distance of transport.
 - b. During travel to select intensive testing areas it became apparent that a nutrient balance or nutrient budget calculator would be an important auxiliary tool. The tool should allow user to determine inputs, outputs and balance of major nutrients. By providing a nutrient budget, farmers or planners can appreciate what their management practices are doing: depleting soils of particular nutrients, adding excess nutrients, or maintaining a balanced nutrient profile. A paper prototype of the nutrient balance tool has been developed to function at different scales: field, farm and farms. It is designed to be used not only within IntDSS, but also as an independent tool that is directly applicable to InterCRSP programs in the African Sahel. The paper prototype is currently under review.
3. Investigators at N.C. State University are assisting the Potash&Phosphate Institute Andean Program (Central-Latin America) to analyze and interpret a P fertilization studies on potatoes that were conducted over several crops and fields. Dominant soils in the area

are Andisols. Each trial contains at least five fertilizer P rates and soil test P was measured during each crop. Ongoing analyses/interpretations focus on determination of critical soil test P levels for potato and estimates of soil P buffer coefficients from field-applied P. This information will help fill knowledge gaps on P diagnosis/prediction/guidance for a particular crop and soil targeted for development in PDSS.

External Funding and Support

Potash&Phosphate Institute Andean Program (Central-Latin America) investments into their field and laboratory research is estimated to exceed \$50,000. Their willingness to share and collaborate on this information represents a direct savings to the project.

Travel and Meetings Attended

none

Relevant Publications, Reports and Presentations at Meetings

none