Annual Progress Report
Decision Aids for Integrated Soil Nutrient Management
February 11, 2000 - February 10, 2001

Executive Summary

Several project activities were either curtailed or stopped during Year 4 to ensure that development of the final version of the NuMaSS software was not compromised by the 13% budget cut. Interim software releases were scaled back and travel to interact with and obtain feedback from extensive network collaborators on software performance was reduced to one trip each to Ecuador and Thailand/Laos.

Software release and evaluation - without the workshop for evaluation of NuMaSS in Year 4, we felt it was important to ensure that any possible user feedback was was incorporated to a interim release of NuMaSS version 1.5 which contained the following improvements over version 1.0: the inputs for each run can be saved, retrieved and re-edited; a check against typos when entering data is provided (range check); and different keyboard configurations for decimal nomenclature can be accommodated. Approximately 140 NuMaSS 1.5 CDs were distributed to collaborators in May and an additional 35 copies were sent to other researchers and managers in both the public and private sectors. Substantial progress was made on NuMaSS 2.0, scheduled for release in Year 5. The diagnosis portion of the interface has been reorganized and simplified based on user feedback. The interface is now much easier to navigate and fewer inputs are required. As navigation has become easier for the user, programming has become more difficult and time consuming. The interface was changed to accommodate an additional crop - peach palm. Over 60 images of plant nutrient deficiencies have been added to the software to facilitate user selection of deficiency symptoms in the diagnosis section. Based on success in addressing nutrient management concerns on an agro-ecological basis, regions of all tropical countries were delineated into three major zones: semi-arid, humid tropical and wet/dry. Agro-ecological zones can be selected in the Geography section or by clicking on a digitized world map. Probabilities for diagnosing N deficiencies and acidity constraints were developed from user survey information to provide a uniform and integrated diagnosis across all nutrients addressed. The project's web site (http://intdss.soil.ncsu.edu) continues to serve as the primary conduit for communications on project activities among U.S. and overseas participants, as well as the general public.

Intensive testing sites -

<u>Costa Rica</u> - measurements were completed for 52-week monitoring of the dry matter distribution and nutrient accumulation among harvested and recycled components of mature peach palm stands in Costa Rica. The combined data for harvested and standing biomass and nutrients reveals the following aspects concerning annual budgets for mature peach palm stands: 1) a total production of 19.0 t ha^{-1} of aboveground dry biomass, of which 69% is cut each year and only 8% is removed for commercial processing of heart-of-palm; 2) the order of ranking for nutrient accumulation is the same in both harvested and standing biomass - K . N>Ca>P>Mg; and 3) of the total nutrient stock in the biomass, quantities exported from the field range from 9% for N and Ca to 11% for P and K. Annual nutrient release in recycled foliage mulch ranges from 67% for Ca to 96% for K. Total aboveground standing biomass for stands up to 20 years old were fit to logistic functions and revealed maximum biomass stabilizing at 5.5 t ha^{-1} at 10 years in stands with < 4200 plants/ha, and 3-4 years in stand with > 4200 plants/ha. Excavations

of plant bases and coarse roots revealed relatively large stores of biomass and nutrients are sequestered belowground in peach palm ecosystems. Cummulative heart-of-palm yields for 29 weeks doubled between fertilizer N rates of 0 and 200 kg ha^{-1} $year^{-1}$, with no additional response between 200 and 400 kg N ha^{-1} $year^{-1}$. Heart-of-palm yields over 12 months did not increase with P fertilization, although soil levels were quite low. Responses to P additions in Brazil were observed in experiments where neither foliar P (young and old leaves) nor soil P at 0-5 and 5-20 cm depths) predicted that a yield response would occur.

Mali - estimates of P buffer coefficients from laboratory incubations compared remarkably well with NuMaSS predicted values for a series of soils in Mali. This suggests that the laboratory incubation is a useful approach for predictions of P requirements in West Africa soils where prior soil test data may not be available. Contrary to local researcher experience and existing prices, 16% of the farmers in the Cinzana region reported use of inorganic fertilizers. Further investigation revealed that fertilizers are applied to selected areas of pronounced nutrient deficiency, rather than uniform applications to entire millet fields. Farmers' reasons for complementing manure applications with fertilizers were to (1) compensate for farmyard manure shortages, (2) poor nutrient quality of the manures, or (3) improve yield of late plantings. Inoculation of cowpea with a mixture of Bradyrhizobium strains from Zimbabwe (N0P2L2)did not increase seed or total biomass yields compared to the control (N0P2L0). Apparently, the indigenous strains had sufficient nitrogen fixation to support N requirements for yield levels under these soil and environmental conditions. An indirect estimate of the amount of N fixed by the cowpea crop is that 28 kg N/ha or 43% of the 65 kg/ha of accumulated N was derived from symbiotic nitrogen fixation.

Philippines - on-farm tests to compare NuMaSS and regional nutrient recommendations with farmer practices and no fertilizer inputs continued with rice and corn in the acid upland soils of Ilagan, Luzon and Arakan Valley, Mindinao. There was a high degree of accuracy in diagnosing constraints of N, P and acidity by NuMaSS. However, the yields achieved for both upland rice and corn were substantially lower than the target yields for which NuMaSS diagnoses and recommendations were made. In general, NuMaSS recommendations resulted in similar yields as the regional recommendation both at the more acid upland site in Ilagan, Isabella and at the less acid site in Arakan Valley for both upland rice and corn crops. Thus, NuMaSS performed as well as the regional recommendation. Peanut, soybean and mungbean BNF were determined by using the total N uptake of a non-nodulating soybean isoline that was included as one of the treatments in experiments at Ilagan. The major effect on BNF was from P application; soybean BNF and total N increased substantially while total N and BNF of peanut and mungbean was influenced less so. The total N uptake was strongly related to P uptake in all legumes. For every unit uptake of P, there was a corresponding uptake of approximately 9 kg N ha^{-1}. It appears that P fertilzation is the key to realizing increased inputs of BNF in acid uplands such as in Ilagan, Isabella, Philippines. Field and laboratory data during the last two crop seasons at Ilagan reveals that rice responded to P in one of two crops, but there was no response to lime or N. Corn responded to lime and P in two crops, but only responded to N in one crop. Peanut, soybean and mungbean responded to P, but response to lime only occurred when green manure was also applied. Preliminary estimates of critical Mehlich 1 P levels in mg kg^{-1} of soil are 6 for rice, 9-18 for corn, 6 for peanut and 5 for soybean.

Enhancing the acidity, N and P knowledge base -

Acidity - Nitrogen fertilization during two corn crops led to rapid acidification of kaolinitic Alfisols at Ibadan, Nigeria. Ammonium sulfate decreased soil pH (water) from 6.2 to 4.5. Incorporation of *Alchornea cordofolia* residue retarded the rate of acidification and leaching of Ca, Mg and NO_3-N during cropping. Movement of NO_3-N in the soil profile corresponded to that of Ca and Mg. Two-year comparisons of Ca movement were completed in Cinzana, Mali on clayey (40%) and sandy soils treated with four rates of lime and corresponding amounts of Ca supplied as Telemsi PR and gypsum. After two millet crop cycles, there was no evidence of Ca movement below 7.5 cm in either soil. Collaborators from Kwazulu-Natal, South Africa provided data for lime trials with *Phaseolus* beans that strengthens the NuMaSS database on this commodity. Critical Al saturation for dry beans across trials on four separate soils was 15%.

Nitrogen - Literature review, data assembly and interpretation for determination of N coefficients was completed for corn, millet and sorghum. Aboveground N accumulation for corn in Africa and Latin America ranged from 0.017 to 0.027 kg N/kg of grain yield. Fertilizer N requirements to achieve optimum yields ranged from 36 to 107 kg ha^{-1}, but were not related to maximum yields which ranged from 3.7 to 7.0 t ha^{-1}. Fertilizer N efficiency values for corn were similar among regions and ranged from 41 to 47%. Fertilizer N efficiency values for most millet trials were similar to corn, but N accumulation and grain:stover ratios varied considerably among both hybrids and improved varieties. A preliminary model to predict N derived from BNF by legumes was developed based on data collected during early soybean growth.

Phosphorus - laboratory incubations to estimate P buffer coefficients were completed for 62 soils (primarily Andisols and Ultisols from Central America). In Andisols, clay content was not related to P buffer coefficients as previously documented for Ultisols and Oxisols. The best predictors for P buffer coefficients in Andisols were either oxalate- or KOH-extractable Al. Critical soil P levels for upland rice and soybean in an acid, soil at Sinoloan, Philippines varied among cropping seasons and increased with the plateau yield level. The soils slow reaction coefficient for applied P was 24% less than the value predicted by NuMaSS. A modified nonlinear regression procedure was developed to extend the applicability of the linear response plateau. Collaborators in Ecuador provided data for three consecutive years of potato trials on Andisols at two separate sites. The field data enable estimation of slow reactions of fertilizer P with the soil over time and critical soil P levels. The Modified Olsen critical soil P level was estimated as 38 mg dm^{-3} across both sites, which was similar to the value of 46 mg kg^{-1} for 19 sites in Western Australia with clay contents ranging from 2-9%. Collaborators in Central Thailand provided opportunities to compare estimates of soil P diagnosis and fertilizer requirements by NuMaSS and local systems for maize. Diagnosis of field kit tests essentially matched those of laboratory soil analyses. Post-harvest soil P values were close to the values predicted by NuMaSS. Although amounts of fertilizer P determined by farmers' methods and NuMaSS were very similar, the latter did a better job of predicting sites were there would be a response.

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 (NuMaSS);
synthesize, analyze and assemble knowledge required to overcome recognized information gaps in the existing information base for acidity, N and P;
test and refine NuMaSS; 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.

Report on project tasks or activities are 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 are also intended to reflect a starting point for the subsequent year's project workplan.

After submission of the annual workplans and budget for year 4, the project was notified that funding for the year would be reduced by 13%. Therefore, the project had to eliminate various planned activities for the year. Activities selected for exclusion during year 4 were selected such that the entire project was not compromised. These activities are listed in the following:

- Objective 1, output 2 - two ongoing field experiments at Cinzana, Mali were stopped;
- Objective 2, output 3 - support to IRRI's Upland Consortium in Asia for field and laboratory data on P among trials in various countries was stopped; and
- Objective 3, output 1 - interim software releases were scaled back as was international travel to interact with and obtain feedback on software performance among members of the extensive evaluation network.

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 Nutrient Management Decision Support System (NuMaSS) Software - merge the three existing single-nutrient decision support system prototypes (acidity, nitrogen, and phosphorus) 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 and combined with a common interface. Milestone events towards development of NuMaSS software, during the 5-year plan are as follows:

- initial NuMaSS prototype developed with each DSS reprogrammed into a common language, computer interface, and using a common database;
- intermediate NuMaSS prototype releases in years 3 and 4 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 NuMaSS in year 5.

Lead Investigators and Contributors:

Deanna Osmond (NCSU) coordinates the NuMaSS software development effort, with inputs from Shaw Reid (N module), Jot Smyth (acidity module) and Russell Yost (P module) through their coordination roles for the individual DSS improvement tasks. Additional contributors to this output during year 2 are listed according to their respective institutions:

University of Hawaii - Xinmin Wang and Nguyen Hue

North Carolina State University - Pedro Luna, Dan Israel, Michael Wagger

Colorado State University - Dana Hoag

Understanding Systems, Inc., Raleigh, NC - Steve Pratt, Will Branch

Progress:

Intermediate release of NuMaSS 1.5 and development for NuMaSS 2.0

1. NuMaSS version 1.5 - Based on user feedback from the Philippines workshop participants, additional changes were necessary for NuMaSS 1.0 beyond what we had anticipated for NuMaSS 2.0. As a consequence, we decided to have an intermediary release, NuMaSS 1.5. Since funding was cut and there wasn't going to be another workshop for evaluation of NuMaSS in year 4, we thought if was extremely important to ensure that any user feedback (especially feedback that we hadn't anticipated) was captured and changes made accordingly. An example of an unanticipated upgrade revolved around numerical nomenclature. Some of our users utilize a period to denote decimals while others use a comma. In order to accommodate these differences in nomenclature, we programmed NuMaSS 1.5 to accommodate both systems. These types of changes that were unforeseen in the original workplan were very time consuming but greatly aid the global transferability of NuMaSS. NuMaSS1.5, which was released in May, has these additional capabilities: the inputs for each run can be saved, retrieved and re-edited, a check against typos when entering data is provided (range check), and different keyboard configurations for decimal nomenclature can be accommodated. In addition, correction of some minor programming errors for all three

programs (ADSS, NDSS, and PDSS) were made. Approximately 140 NuMaSS 1.5 cds were distributed to collaborators, in both intensive and extensive evaluation groups. An additional 35 copies of NuMaSS 1.5 were sent to other researchers and managers both in the public and private sector.

2. NuMaSS 2.0 Interface - In addition to releasing NuMaSS1.5, we have made substantial progress on NuMaSS 2.0. The diagnosis portion of the interface has been reorganized and simplified based on user feedback. The interface is now much easier to navigate and fewer inputs are required. As navigation has become easier for the user, programming has become more difficult and time consuming. The interface was changed to accommodate an additional crop - peach palm. Because characteristics of peach palm are so much different from annual crops, several new input boxes have been added. The addition of these input boxes for peach palm have been iterative since we had to collect, analyze and interpret the information from the peach palm experiments before we could determine the types of questions to ask the users. We are just now finalizing information and the algorithms for peach palm in the *Diagnosis* and *Prediction* sections of NuMaSS 2.0 based on recently analyzed data.
3. Images for Diagnosis - We obtained over 60 slides of plant nutrient deficiencies for 9 commodities. These images are available in the diagnosis section of NuMaSS 2.0 as thumbnails. Possible nutrient deficiencies shown are N, P, K, Ca, Mg, and acidic conditions that includes Mn toxicity. If the user wants to enlarge the thumbnail, clicking on the image increases the size. These images of plant nutrient deficiencies will greatly aid the user in making correct selections in diagnosis. Authorship of the images has been fully credited. Crops and nutrient deficiencies are as follows: Corn (N, K, Ca, Mg, & P); Rice (K, N, & acidity); Sorghum (N, P, KI, Ca, Mg, & Mn toxicity); Wheat (N); Soybean (K, N, & Mn toxicity); Peanut (N, K, Ca, & Mg); Cotton (P, K, Mg & Mn toxicity); Potato (N, P, K, Mg, & Ca); Peach palm (K, Mg, N, & P); Cowpea (K & Mg).
4. Agroecological Maps - Based on results from the workshop and the success in dealing with nutrient management issues and concerns on an agroecological basis, we decided to use these regions to accomplish some data base queries. Using climatic maps generated by Dr. Van Wambeke of Cornell, we divided all the tropical countries into three agroecological zones: semi-arid, humid tropical, and wet/dry (Table 1). Some countries are only in one agroecolgical zone, some are in all three. Agroecological region can either be selected in the *Geography* section or by clicking on the map. We digitized the world map to allow for this method of selection.

Table 1. Agroecological zones assigned to countries in each continent for the *Geography* section of the *Diagnosis* component of NuMaSS 2.0.

Country	**Agroecosystem**
AFRICA	
Angola	semi-arid, wet/dry
Benin	wet/dry, humid tropical
Botswana	semi-arid, wet/dry
Burkina Faso	wet/dry, semi-arid
Burundi	humid tropical, wet/dry
Cameroon	semi-arid, wet/dry, humid tropical
Cape Verde	n/a

Country	Agroecosystem
Central African Republic	semi-arid, wet/dry
Central African Republic	humid tropical
Chad	semi-arid, wet/dry
Comoros	n/a
Democratic Republic of the Congo	wet/dry, humid tropical
Equitorial Guinea	humid tropical
Eritrea	semi-arid
Ethiopia	semi-arid, wet/dry
Gabon	humid tropical
Ghana	wet/dry, humid tropical
Guinea	wet/dry, humid tropical
Guinea-Bissau	wet/dry
Ivory Coast	wet/dry, humid tropical
Kenya	semi-arid, wet/dry, humid tropical
Lesotho	wet/dry
Liberia	humid tropical
Madagascar	semi-arid, wet/dry, humid tropical
Malawi	wet/dry
Mali	semi-arid, wet/dry
Mauritania	semi-arid
Mauritius	n/a
Mayotte	n/a
Mozambique	semi-arid, wet/dry
Namibia	semi-arid
Niger	semi-arid, wet/dry
Nigeria	semi-arid, wet/dry, humid tropical
Republic of the Congo	humid tropical
Reunion	n/a
Rwanda	humid tropical, wet/dry
Saint Helena	n/a
Sao Tome and Principe	n/a
Senegal	semi-arid, wet/dry
Seychelles	n/a
Sierra Leone	humid tropical
Somalia	semi-arid
South Africa	semi-arid, wet/dry
Sudan	semi-arid, wet/dry
Swaziland	wet/dry, semi-arid
Tanzania	semi-arid, wet/dry, humid tropical
The Gambia	wet/dry
Togo	wet/dry, humid tropical
Uganda	wet/dry, humid tropical
Zambia	wet/dry
Zimbabwe	wet/dry, semi-arid

Country	**Agroecosystem**
Central America	
Guatemala	wet/dry, humid tropical
Honduras	humid tropical, wet/dry
Nicaragua	humid tropical, wet/dry
Mexico	wet/dry, humid tropical, semi-arid
Panama	humid tropical, wet/dry
Costa Rica	humid tropical, wet/dry
El Salvador	wet/dry
Belize	humid tropical
SOUTH AMERICA	
Argentina	wet/dry, humid tropical, semi-arid
Bolivia	wet/dry, humid tropical, semi-arid
Brazil	wet/dry, humid tropical, semi-arid
Chile	wet/dry, humid tropical, semi-arid
Colombia	wet/dry, humid tropical, semi-arid
Equador	wet/dry, humid tropical, semi-arid
French Guinea	humid tropical
Guyana	humid tropical, wet/dry
Paraguay	wet/dry, humid tropical
Peru	wet/dry, humid tropical, semi-arid
Suriname	humid tropical, wet/dry
Uruguay	humid tropical, wet/dry
Venezuela	wet/dry, humid tropical, semi-arid
ASIA	
Bangladesh	humid tropical
Burma	humid tropical, wet/dry
Cambodia	humid tropical
China	wet/dry, humid tropical, semi-arid
Indonesia	humid tropical
India	wet/dry, humid tropical, semi-arid
Laos	humid tropical
Malaysia	humid tropical
Papua New Guinea	humid tropical
Philippines	humid tropical
Singapore	humid tropical
South Korea	humid tropical
Sri Lanka	wet/dry, humid tropical
Taiwan	humid tropical
Thailand	humid tropical
Vietnam	humid tropical
CARIBBEAN	
Cuba	humid tropical, wet/dry
Dominican Republic	humid tropical
Haiti	wet/dry, humid tropical

Country	Agroecosystem
Jamaica	wet/dry, semi-arid
Puerto Rico	semi-arid, humid tropical
Santa Domingo	humid tropical

5. Diagnosis Probability Values - One of the differences between PDSS and the other two modules was the use of probabilities in the diagnosis section. In order to provide a uniform and integrated system, it was necessary to develop probabilities for N deficiency and acidic conditions. Using survey information derived from our users, we developed probabilities for nitrogen deficiencies and acidic problems. These probabilities have been incorporated into the diagnostic portion of NuMaSS 2.0 (Table 2). The probability section is functioning well.

Table 2. Probability values for diagnosis of annual crops in NuMaSS 2.0.

	Probability		
Diagnostic Question	**Acidity**	**Nitrogen**	**Phosphorus**
Region			
Humid tropical	0.50	NA	NA
Semi-arid	0.45	NA	NA
Wet/Dry	0.50	NA	NA
Amazon	NA	NA	0.70
Cerrado	NA	NA	0.70
Niger	NA	NA	0.70
Mali	NA	NA	0.72
Sitiung	NA	NA	0.80
Other	NA	NA	0.50
Soil order			
Alfisols	0.57	0.74	0.50
Andisols	0.50	0.56	0.68
Aridisol	0.50	0.79	0.50
Entisols	0.58	0.68	0.51
Gelisol	0.50	0.50	0.50
Histosols	0.50	0.25	0.45
Inceptisols	0.66	0.69	0.49
Mollisols	0.50	0.65	0.37
Oxisols	0.75	0.85	0.68
Spodosols	0.50	0.90	0.47
Ultisols	0.75	0.85	0.68
Vertisols	0.50	0.66	0.50
Prev. Crop Yield/Fallow			
Forest fallow >10 yrs	0.55	0.01	NA
Forest fallow < 10 yrs	0.35	0.05	NA
[a]High yield<20Al – Crop>40Al	0.45	NA	NA
High yield<40Al – Crop>60Al	0.45	NA	NA
Savanna fallow	NA	0.20	NA

Grain legume	NA	0.45	NA
Green manure	NA	0.15	NA
Soil Analysis			
*AlSat/AlSat$_c$ > 1.5	0.75	NA	NA
*pH – pH$_c$ < 1.0	0.75	NA	NA
Ca < 1.0 cmol kg^{-1}	0.74	NA	NA
MgSat/10 < 0.5	0.74	NA	NA
**Truoug	NA	NA	0.73
**Mehlich3	NA	NA	0.74
**Mehlich1 (1:10)	NA	NA	0.69
**Bray1	NA	NA	0.79
**Olsen	NA	NA	0.78
Crop Deficiency Symptoms (Images)			
Stubby Stunted roots (Acidity)	0.77	NA	NA
Mn toxicity (Acidity)	0.60	NA	NA
Purplish lower leaves (P)	NA	0.72	NA
Thin stalks (P)	NA	NA	0.58
Yellow leaf tip & midribs (P)	NA	NA	0.44
Yellow lower leaves (P)	NA	NA	0.43
Yellow lower leaves (N)	NA	0.70	NA
Plant Analysis			
N	NA	0.74	NA
*Ca/Ca$_c$<0.5	0.79	NA	NA
*Mg/Mg$_c$>0.5	0.77	NA	NA
*Mn/Mn$_c$>1.5	0.77	NA	NA
Indicator Plants			
Melastoma	0.70	NA	0.65
Molasses grass	NA	NA	0.60
Eupatorium Odoratum	NA	NA	0.51
Fern	0.70	NA	NA
Leucaena leucocefala	0.47	NA	NA

[a] High yield of a previous crop with a critical Al saturation % of 20 or less for diagnosis of a target crop with a critial Al saturation % of 40 or greater.

* Subscript "c" means critical values that will be pulled from a table for the previous crop.

** Different soil tests used for determining soil P.

In addition, a survey was developed by Jot Smyth, Russ Yost, Adrian Ares and Deanna Osmond for the probability of nutrient deficiencies and acidic problems for peach palm. The survey was sent to contacts from our extensive testing partners in Central and South America. Based on their responses, we analyzed their answers and added the probability information found in Table 3 for peach palm to NuMaSS 2.0.

Table 3. Probabilities for diagnosis of palmito in NuMaSS 2.0.

Parameter	**Probability**				
	Acidity	**Ca**	**Mg**	**N**	**P***
Soil Order					
Andisol	0.48	0.58	0.65	0.93	
Entisol	0.30	0.36	0.39	NA	
Inceptisol	0.54	NA	NA	0.73	
Oxisol	0.65	0.75	0.78	0.83	
Ultisol	0.39	0.68	0.68	0.82	
Alfisols	NA	0.45	0.45	0.50	
Other	NA	NA	NA	0.50	
Region					
Brazil (Amazon)	NA	0.73	0.78	0.83	
Brazil (Chapare)	NA	NA	NA	0.74	
Costa Rica (Atlantic)	NA	NA	NA	0.94	
Costa Rica (Pacific)	NA	NA	NA	0.90	
Other	NA	0.63	0.64	NA	
Visual Symptoms (images)					
Establishment	NA	0.69	0.67	NA	
Fast growth	NA	0.74	0.78	NA	
Mature	NA	0.74	0.78	NA	
Yellow old leaf establishment	NA	NA	NA	0.78	
Yellow old leaf fast growth	NA	NA	NA	0.80	
Yellow old leaf mature	NA	NA	NA	0.80	
Light green old leaf establishment	NA	NA	NA	0.71	
Indicator Plants					
Andropogon bicornis (Chapare only)	NA	NA	NA	0.77	
Ferns	NA	0.76	0.76		
Previous Land Use					
Palmito	NA	0.40	0.40		
Other crops**	NA	0.40	0.40		
Previous Growth					
Fast growth good	NA	0.50	0.51	0.73	
Mature growth good	NA	0.50	0.51	0.72	
Fast growth <50%	NA	0.50	0.50	0.91	
Mature < 50%	NA	0.50	0.55	0.87	
Leaf Tissue Concentration					
< 50% of critical concentration: Establishment	NA	0.63	0.63	0.87	
< 50% of critical concentration: Fast	NA	0.73	0.74	0.87	
< 50% of critical concentration: Mature	NA	0.71	0.66	0.90	
>150% of critical concentration: Est.	NA	0.37	0.37		
>150% of critical concentration: Fast	NA	0.27	0.26	0.13	
>150% of critical concentration:Mature	NA	0.29	0.34	0.10	

Parameter	Probability				
	Acidity	Ca	Mg	N	P*
<150% & > 50% Establishment	NA	0.50	0.50	0.50	
<150% & > 50% Fast	NA	0.50	0.50	0.50	
<150% & > 50% Mature	NA	0.50	0.50	0.50	

* Probabilities for P not yet available
**If a previous crop other than palmito had good yields and has default % Al saturation < 40 or if humid tropics and establishment immediately preceded by slash-burn clearing of forest.

Foliar criteria in the diagnostic portion of pach palm was based on the tentative foliar critical levels for peach palm shown in the Table 4.

Table 4. Critical foliar nutrient levels used for the *diagnosis* portion of the peach palm module.

Leaf	Ca	Mg	N
	-------------- % ---------------		
3rd	0.40	0.25	2.5
5th	0.60	0.35	2.0

6. Maintenance of the project's web site - The project's web site (http://intdss.soil.ncsu.edu) continues to serve as the primary conduit for communications on project activities among U.S. and overseas participants, as well as the general public. The site's calendar section alerted all members to pending deadlines and provided advanced notification of travel schedules throughout the year. Reports on each travel event, workplans, workshops, annual progress, baseline surveys and "white papers" were produced in Acrobat Reader file format (*.pdf) and posted on the website for downloading by interested viewers. The FTP site on the project's server expedites the exchange of NuMaSS software files among programmers at N.C. State and Hawaii universities. The FTP site allowed selected users access to download NuMaSS, 1.5. Following the workshop in the Philippines an e-mail listserver was also created to facilitate continued correspondence and consultation with collaborators.
7. Initial Prototype of Nutrient Management Guidance Module (Deanna Osmond, Jot Smyth, Shaw Reid, Russell Yost and Dana Hoag) Last year we reported a second two-day working meeting was held with Dr. Dana Hoag, an agricultural economist at Colorado State University, to discuss integration of the three models within the *Guidance Section* of NuMaSS. Concurrence was reached between the four principle investigators and Dr. Hoag that the economic integration would proceed initially as a linear plateau model.
   A data set on soil characteristics, crop yields, and commodity prices was collected for the Cerrado region of Brazil. This data set was forwarded to Dr. Hoag who was able to develop a preliminary algorithm using Excel. We are verifying that the model correctly predicts fertilizer rates based on the linear-plateau model we proposed and as programmed by Dr. Hoag.
   Currently, the three nutrient DSS modules have very different input needs for the economic section. Dr. Hoag reviewed these data needs and developed a power point presentation that will serve as a reference point for developing the Economics interface in NuMaSS 2.0. An

example of the interface prototype is presented Figure 1. We identified those components most important to an integrated module: type of fertilizer selected, fertilizer cost, transportation cost, application cost, and commodity price.

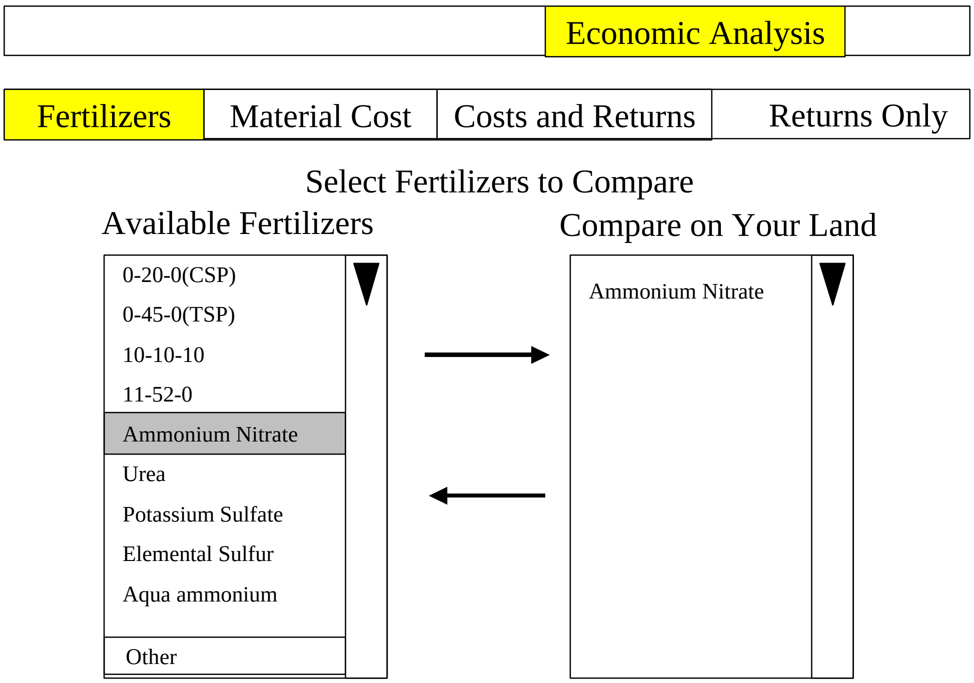

Figure 1. Example of the interface under design for the *Economics* section of NuMaSS 2.0.

Environmental Concerns

1. Written Units (Deanna Osmond) - Information has been collected and units on the agricultural sources and affects of N and P are being written. Using N as an example, information has been collected on the N cycle, mode of transport, water quality limits, health affects, environmental affects, and agricultural sources. We have used multiple sources to collect this information. The information has been written and edited and is going through an additional review. After the review, the information will be changed into "fact sheets" and these informational units or "fact sheets" will be added to NuMaSS for release 2.0.
2. Peach Palm Work - Nitrogen losses from agricultural activities to coastal water resources is an increasing problem. Results from the suction lysimeter measurements in N fertilization experiments of peach palm production at different fertilizer rates is documenting NO_3-N losses and potential movement into ground water (See "Costa Rica" section on Output 2 of this Objective). Once this relationship between NO_3-N losses and fertilizer rates are finalized, this information will be added to NuMaSS 2.0 as a "fact sheet."

Predicting residual nutrient value

The nitrogen contribution of green manures to crop production has been incorporated into NuMaSS 1.5. The green manure information that has been collected was analyzed (see section on Output 2 of Objective 2) and N content is shown to be a function of the yield of the green manure crop. In addition, the N contribution of legumes (if stover is left in the field) has been incorporated into NuMaSS. The other residue that contributes to nutrient value that the project has reviewed is peach palm residue. Results from research reported in this report on decomposition of peach palm residue (see "Costa Rica" section on Output 2 of this Objective) is demonstrating a large release of N, P, K, Ca and Mg that continues to recycle through the system to be re-utilized by the peach palm crop.

External Funding and Support

None

Travel and Meetings Attended

Osmond, D.L. *Developing a Nutrient Management Decision Support System for the Tropics*. Cornell University, Department of Crops and Soil. Invited presentation.

Relevant Publications, Reports and Presentations at Meetings

Osmond, D.L., T.J. Smyth, W.S. Reid, R.S. Yost, W. Branch and X. Wang. 2000. Nutrient Management Support System, NuMaSS (Version 1.5). Soil Management Collaborative Research Support System, North Carolina State University, Raleigh, NC.

Initial Prototype of Nutrient Management Guidance Module (Power point presentation and excel spreadsheet) D. Hoag (Colorado St. Univ.) for (D.L. Osmond and T.J. Smyth (NCSU), W.S. Reid (Cornell Univ.), and R.S. Yost (Univ. of Hawaii).

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

The process of developing the NuMaSS 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.

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

<u>Lead Investigators and Contributors</u>

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, Raphael Salas, and Eloy Molina; Costa Rican Ministry of Agriculture/'Los Diamantes' Experiment Station - Antonio Bogantes; 'Agropecuaria Rio Frijoles' - Enrique Berrocal and Martin Sanchez;

Institute d'Economie Rurale, Mali - Mamadou Doumbia, Aminata Sidibe, Adama Bagayoko, Mamadou Diarra, Kamidou Konare (Sotuba Station); Adama Coulibaly, Oumar Coulibaly, Birama Coulibaly, Diakalia Sogodogo and Zoumana Kouyate (Cinzana Station)

Philippine Rice Research Institute/IRRI - Teodula Corton, Santiago Obien, Josephina Lasquite, Miguel Aragon and Madonna Casimero (PhilRice) and Thomas George (IRRI)

All the project's U.S. team members contribute to intensive testing site activities through their individual tasks (see Objective 2, Outputs 1-3).

<u>Progress</u>

1. *Costa Rica*

   <u>Ongoing laboratory, greenhouse and field experiments</u>

   1. Biomass and nutrient accumulation in 4- and 8-year peach palm stands - (supervised by Eloy Molina and Jimmy Boniche at UCR and Antonio Bogantes at MAG, with support from Michael Wagger and Jot Smyth) this experiment was completed during the year. The objective was to characterize seasonal distribution of annual dry matter and nutrient accumulation among harvested and recycled components of mature peach palm stands managed for heart-of-palm production. The study was performed on 4- and 8-year stands at MAG's 'Los Diamantes' Experiment Station at Guapiles. Offshoot were harvested at 4-week intervals across 52 consecutive weeks, and aboveground biomass, N, P, K, Ca and Mg was determined in materials that are exported or recycled as residue mulch.

Although there were seasonal differences in the number of offshoots harvested or pruned, the cumulative number of offshoots and biomass harvested, and their accumulated nutrient content across the 12-month period was similar for both stands. A mean total of 13.1 t ha^{-1} of dry matter was cut during the year, of which only 1.43 t ha^{-1} (11%) was removed from the field as 11,214 hearts-of-palm and protective inner stem sheaths (Table 5). Because offshoots are harvested when they achieve a specified basal stem diameter, a good relation (r^2=0.97) was obtained across all sampling dates and stands between number of harvested 'palmito' and dry weight for the sum of foliage (leaves, rachis and petioles), stem sheaths and heart-of-palm. This means that total dry weight of cut offshoots can be easily predicted in NuMaSS from user input for number of harvested palmito through multiplication by a constant value of 1.04 kg/palmito. Likewise, estimation of the recycled residues can be calculated by subtraction of the proportion of this total harvested dry matter which is exported from the field for commercial processing.

Table 5. Mean dry weights and nutrient content for shoot components of 11,214 harvested hearts-of-palm and pruned excess offshoots from 4- and 8-year peach palm stands over a 52-week period. Mean values are based on six plot replicates in each stand.

	Harvested Offshoots					
		Stem Sheaths			**Pruned**	
	Foliage	**Outer**	**Inner**	**Heart-of-palm**	**Offshoots**	**Total**
	---------------------------------- kg ha^{-1} ----------------------------------					
Dry Matter	8,524	2,779	789	637	416	13,145
N	129	19	5	17	7	177
P	21	8	2	4	1	36
K	114	40	11	20	7	192
Ca	31	10	3	3	1	48
Mg	17	6	1	3	1	28

Accumulation of nutrients in harvested and pruned excess offshoots was in the order of K.N>Ca>P>Mg (Table 5). Among these nutrients, however, proportions exported from the field as heart-of-palm and protective inner stem sheaths ranged from 12 to16%. Linear relations (with r^2>0.96) between nutrient accumulation and dry weight of harvested offshoots were also developed to enable prediction in NuMaSS of total nutrient content for a given level of harvested palmitos; these regressions indicate that the mean nutrient concentrations in harvested offshoots are 1.40% N, 0.27% P, 0.37% Ca, 0.21% Mg and 1.60% K.

On any given harvest date in mature peach palm stands there is a certain fraction of standing biomass which is in equilibrium with the offshoots with are ready to be harvested. This standing biomass consists of a certain number (6-9) of offshoot at different stages of development which will be harvested at future dates. We estimated the standing biomass and nutrient content by destructively sampling all plants in each plot after the final harvest at 52 weeks (Table 6).

Table 6. Mean dry weight and nutrient content of standing aboveground biomass for developing offshoots after the final harvest of heart-of-palm at 52 weeks in the 4- and 8-year peach palm stands.

Dry Matter	**N**	**P**	**K**	**Ca**	**Mg**
---------------------------------- kg ha^{-1} ----------------------------------					
5,879	72	20	92	17	12

The combination of data for harvested and standing biomass and nutrients reveals the following aspects concerning annual budgets for mature peach palm stands: 1) a total production of 19.0 t ha^{-1} of aboveground dry biomass, of which 69% is cut each year and only 8% is removed for commercial processing of heart-of-palm; 2) the order of ranking for nutrient accumulation is the same in both harvested and standing biomass - K.N>Ca>P>Mg; and 3) of the total nutrient stock in the biomass, quantities exported from the field range from 9% for N and Ca to 11% for P and K.

b. Decomposition and nutrient release from crop residues of harvested offshoots for heart-of-palm - (UCR supervision by Gabriela Soto, Eloy Molina and Jimmy Boniche with assistance from Michael Wagger, Pedro Luna and Jot Smyth) this field experiment in a 16-year commercial peach palm stand near Guapiles has the objective of characterizing the rates of decomposition and nutrient release from the large quantities of foliage which are cut with each harvested heart-of-palm and left in fields as a mulch. Fiber glass mesh bags with harvested foliage were placed on the soil surface between peach plant rows. The bags were collected at nine dates over a 48-week period and analyzed for remaining dry matter and nutrient content. There were three series of bags distributed across 48-week periods encompassing 1.5 years. Final samples were collected and prediction equations for dry matter decomposition and nutrient release were completed during this year. A preliminary description of the results and the prediction equations were described in the annual report for project year 3. There were no significant differences in foliage decomposition and nutrient release between the three 48-week periods investigated. Thus, all observations were pooled for development of prediction models. With the exception of K release which fit a single exponential model, % dry matter loss or release of other nutrients were best described by an asymptotic model.

Prediction models developed in this study were applied to harvested foliage in the previously-reported trial where palmitos were harvested at 4-week intervals across a 12 month period. Nutrient release of foliage residue mulch for each harvest was estimated for the remaining period during the 12 months and summed to derive the total annual release. Predicted annual nutrient release from foliage residue are compared in Table 7 with annual totals for nutrients in the residue pool, uptake and fertilizer inputs for the 4-year stand. Comparisons of total uptake in harvests with fertilizer inputs reveals that uptake exceeds annual applications for N, P, K and Ca. However, appreciable amounts of the annual nutrient uptake can be accounted through recycling of nutrients from the decomposition of foliage residue left in the field as a mulch. Annual release of nutrients in the foliage ranges from 67% for Ca to 96% for K. The potential needs for fertilizer inputs was estimated as the difference between total uptake in harvests and the predicted release from foliage residue. Comparisons between actual fertilizer added and potential fertilizer needs reveals that P and K fertilizer inputs match the estimated needs, whereas there may be an excess in N and Mg inputs and a draw-down of soil Ca reserves. However, these estimates assume 100% efficiency in uptake of nutrients recycled from foliage residues and do not consider uptake efficiencies for nutrients added in fertilizers.

Table 7. Comparisons between nutrients added in fertilizers, accumulated in harvested and pruned offshoots, and release from foliage residue mulch during a 12-month period in a 4-year peach palm stand.

	N	**P**	**K**	**Ca**	**Mg**
Fertilizer added (kg ha^{-1})	155	19	108	0	31
Total uptake in harvests (kg ha^{-1})	161	36	210	44	26
Foliage residue nutrients released (kg ha^{-1})	93	15	116	19	13
% Foliage residue nutrient release	81	73	96	67	85
Potential fertilizer uptake (kg ha^{-1})[a]	68	21	94	25	13

[a] Nutrient uptake in harvests - nutrients released in foliage residues

c. N fertilization field trial - (supervision by Eloy Molina, Alfredo Alvarado, Gabriela Soto, Rafael Salas, Jimmy Boniche of UCR and Antonio Bogantes of MAG with assistance from Shaw Reid, Michael Wagger, Deanna Osmond and Jot Smyth) since N is one of the major nutrient needs for mature peach palm stands and, in the absence of other field trials, an experiment was started during the year to characterize palmito yield response to fertilizer N. The experiment was started on May 22, 2000 in a 5-year stand at MAG's 'Los Diamantes' Experiment Station on a soil classified as Aquandic Dystrudepts. Selected chemical properties are shown in Table 8 for the surface 15-cm layer. Prior to starting the N experiment, the standard harvest and pruning management, and fertilization (except N) was applied to the stand to develop uniformity in the number of offshoot per plant. Fertilizer N treatments include 0, 50, 100, 200 and 400 kg ha^{-1} as NH_4NO_3 (the standard N source recommended for peach palm in Costa Rica), and 100 kg ha^{-1} as urea. In all these treatments crop residues a left in the field as mulch. In an additional zero-N treatment crop residues are removed with each harvest to provide comparisons between native soil N contributions and the crop residues. All N fertilizers and blanket rates of P, K and Mg are surface-applied in bands between plant rows as equal split-applications every 60 days. Each plot consists of four 10-m plant rows with treatments arranged in a randomized complete block design with three replications.

Table 8. Selected initial properties for the surface soil layer 0-15cm of the site for the N fertilization trial.

pH in	**Olsen-Extractable**			**KCl-Extractable**		**Olsen**	**Al**	**Org.**
H_2O	**Ca**	**Mg**	**K**	**NH_4**	**NO_3**	**P**	**Sat.**	**Matter**
	---------- cmol L^{-1} ----------			---------- mg L^{-1} ----------			----- % -----	
5.0	4.14	1.05	0.25	12.8	3.0	25.0	15	4.28

Cumulative palmito yields during the first 29 weeks of the experiment are shown in Figure 2. Palmito yields essentially doubled between 0 and 200 kg N ha^{-1}, but there was no additional yield increase between 200 and 400 kg N ha^{-1}. The effect of N release from crop residues was also evident by the end of the 29 weeks, where yield for the zero-N treatment with residue removal was significantly less than for the zero-N treatment where residues at each harvest are left in the field as a surface mulch. Palmito harvests will continue to be monitored at 4-

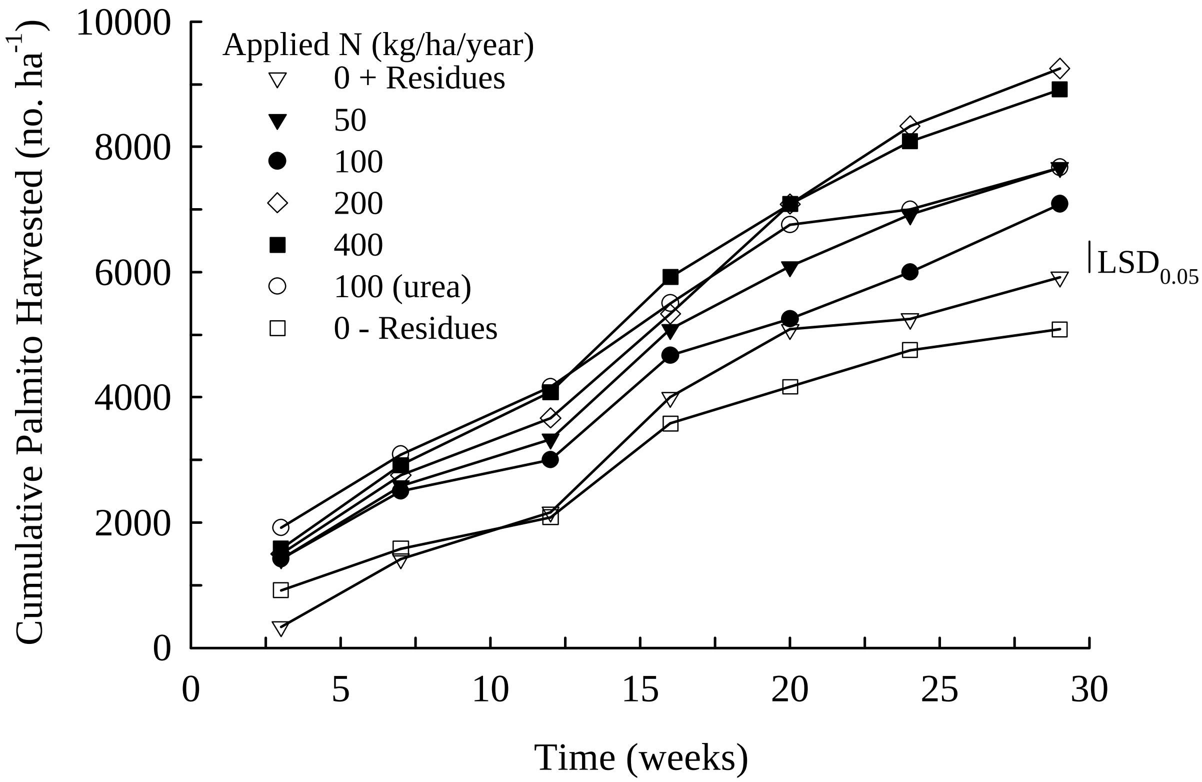

Figure 2. Cumulative heart-of-palm yield as a function of fertilizer N and residue treatments during the first 29 weeks.

week intervals for a 12-month period. Harvested plant components are being analyzed for N content in order to develop an annual N budget for each treatment. Diagnostic leaf tissue are also sampled every trimester and analyzed for N.

Suction lysimeters at three depths (5, 20 and 40 cm) are used to access N movement in three of the fertilizer N treatments. Samples are drawn during each 60-day period between fertilizer N applications and analyzed for NH_4 and NO_3. Trends in solute N distribution with time after the first surface application of fertilizer N are shown in Figure 3. Nitrogen movement to 20 cm was evident for annual N rates of both 200 and 400 kg ha^{-1} (only 33.3 and 66.6 kg ha^{-1} applied thus far) at seven days after application. Residence time of N at this intermediate depth extended to 45 days. Significant increases in solute N at 40 cm were only detected for the treatment with 400 kg N ha^{-1}, which is an N level that thus far exceeds the crop requirements for maximum palmito yield (Figure 2).

Initial project surveys revealed that some farmers were applying up to 400 kg of N ha^{-1} $year^{-1}$. If the initial results for palmito yield and N movement are sustained during continuation of this experiment, fertilizer N recommendations could be reduced with potential alleviation of N movement to groundwaters, improved efficiency of fertilizer N use, and reduced fertilizer costs.

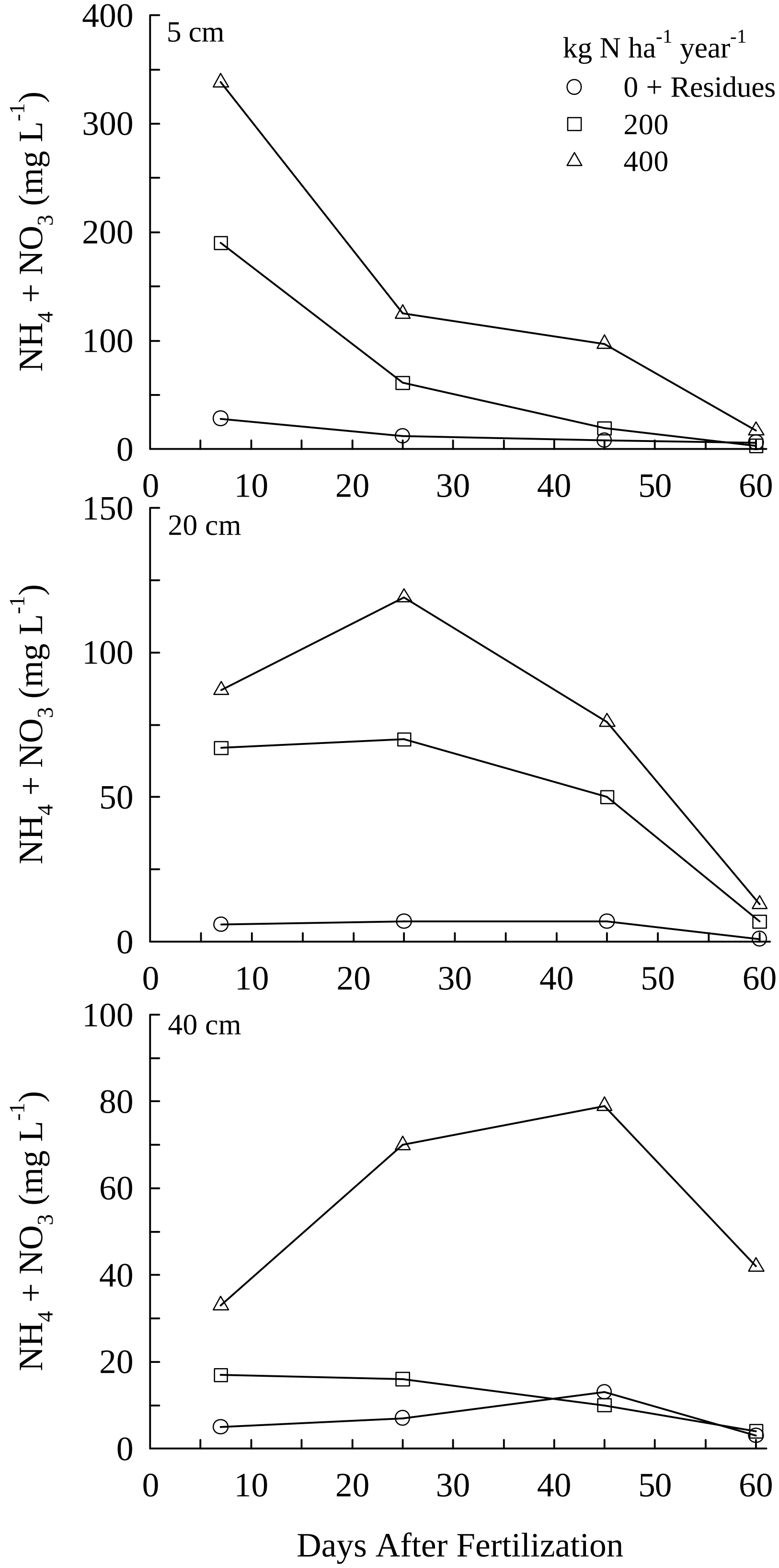

Figure 3. Ammonium and $N0_3$ distribution in suction lysimeter solutions as a function of soil depth, N treatments and time.

d. Patterns of biomass accumulation - (supervised by Eloy Molina and Jimmy Boniche at UCR with support from Adrian Ares and Russell Yost) Perennial tree crops develop through growth phases that differ in the rates of biomass and carbon build-up, and in the relative contribution of various stores to fluxes in nutrient cycles and nutrient supply for plant growth (Figure 4). To define these phases in peach palm (*Bactris gasipaes*) agroecosystems for heart-of palm production, we estimated biomass stores in stands up to 20 years old in the humid tropical lowlands of Costa Rica. Dry biomass of foliage, petioles and stems were estimated using allometric equations which were previously generated by applying nonlinear seemingly unrelated regression procedures to harvest data from of peach palm plants (Figure 5). Total aboveground biomass trajectories through time were fit to three-parameter logistic

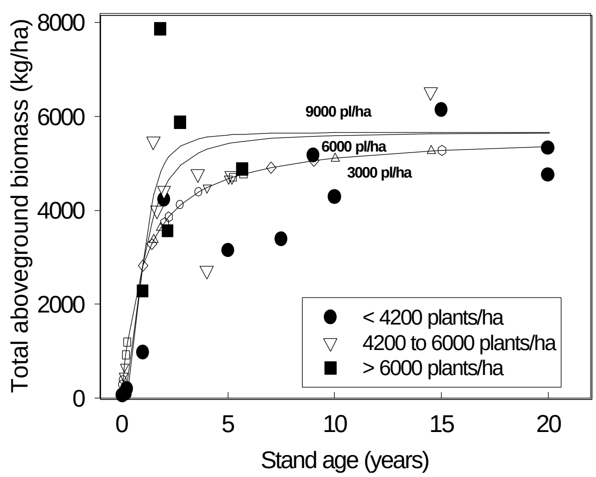

Figure 4. Standing biomass through time in peach palm stands in the Atlantic Region of Costa Rica. Curves were calculated from fitted equation and predicted values are given in the solid lines for 3000, 6000, and 9000 plants / ha.

functions with total biomass stabilizing at about 5.5 Mg/ha at age 10 in stands with less than 4200 plants/ha, and at 3-4 years in stands with more than 4200 plants/ha (Figure 4). There were no differences in aboveground biomass between stands on Andisols and Ultisols. Trends in nutrient stores through time were similar to those for biomass. Excavations of peach palm plant bases and coarse roots ('spiders') suggested that there are relatively large biomass stores and, subsequently, carbon and nutrients sequestered belowground in peach palm agroecosystems. The amount of carbon per unit area in plant tissues in peach palm agroecosystems in the Atlantic Region of Costa Rica is about 8 % of the carbon in forests of the same region.

<u>Development and validation of allometric equations, and generation of functions to predict biomass accumulation of peach palm through time for the phosphorus and nitrogen modules of NuMass</u> - We analyzed harvest data obtained in 1999 using a nonlinear seemingly unrelated procedure (NSUR) which simultaneously fits the component equations that predict

leaf, petiole and stem in order to assure biomass additivity (Figure 5). Equation coefficients for NSUR fitted-regressions that also model equal variances were substantially different from those for individual regressions which independently calculates equation coefficients (e.g., $Biomass_{leaf} = 11.47\ BD^{1.8042}$ for the individual equation versus $Biomass_{leaf} = 6.84\ BD^{2.086}$ for the NSUR fitted-equation). NSUR equations had slightly less precision in estimating biomass that individual equations but consistently less bias.

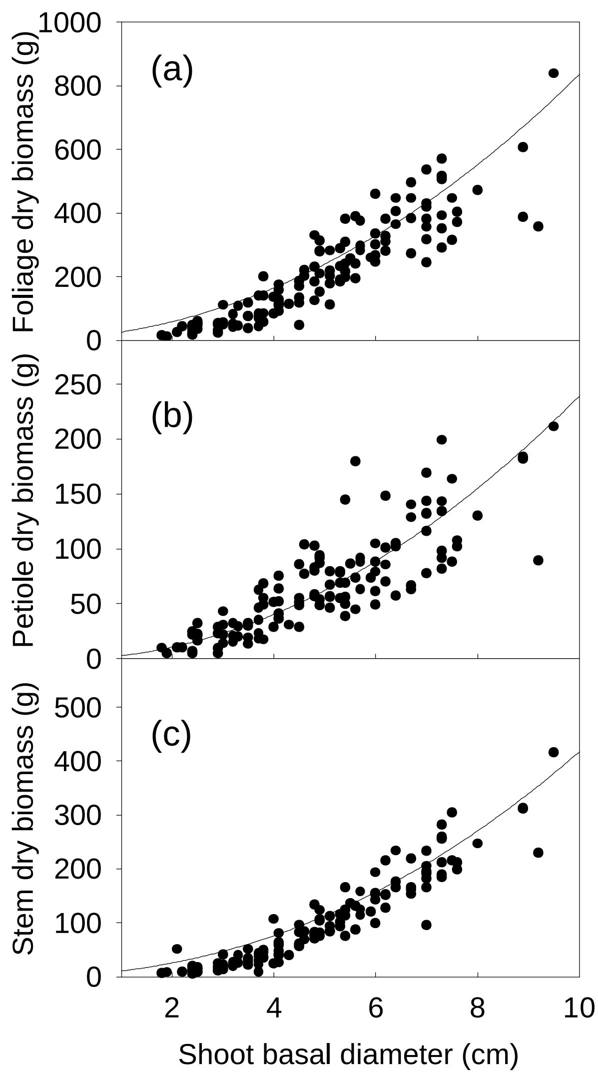

Figure 5. Relationships between shoot basal diameter and (a) foliage, (b) petiole, (c) stem dry biomass for peach palm in the Atlantic region of Costa Rica. Allometric functions derived from nonlinear seemingly unrelated regressons (NSUR) are presented by solid lines.

To validate the developed equations, we harvested peach palm plants within four stands ranging in age from 1.9 to 21 years. Estimates of component and total aboveground shoot biomass were similar to observed values except for the youngest stand in which biomass was overestimated. In another harvest, yield of heart-of-palm per plant was linearly related to total aboveground biomass in two peach palm stands of age five and nine years.

To define growth phases in peach palm, we estimated biomass in stands up to 20 years old in Costa Rica. Dry biomass of plant components were estimated using the allometric equations generated previously. Total aboveground trajectories through time were fitted by three-parameter logistic functions with total biomass stabilizing at about 5.5 Mg/ha. The order in size of nutrient pools was N (up to approximately 120 kg/ha) > K (up to 90 kg/ha) > Ca (up to 40 kg/ha) > S, P (both up to 16 kg/ha) > Mg (up to 15 kg/ha). In the examined stands, there were no significant changes with stand age in soil organic carbon, soil pH, exchangeable acidity and soil macro and micronutrients. In a mature peach palm stand on an Andisol, there is approximately 8.0 Mg C ha^{-1} in aboveground biomass and 83 Mg C ha^{-1} in the topsoil.

We also excavated the belowground biomass component in peach palm stands ranging in age from 2 to 21 years and with an initial density of 5000 plants/ha. The trajectory of the ratio of belowground to aboveground biomass through time fitted a rectangular, two-parameter hyperbola and varied between one in young stands to more than two in mature stands. On an area basis, there may be more than 10 Mg/ha of belowground biomass in a mature peach palm stand. This indicates that relatively large stores of carbon and nutrients are underground in peach palm stands.

Because of the important of the yield of hearts-of-palm, the allometric equations were examined to determined if they could be used to estimate yields of the commercial product – hearts-of-palm (Figure 6). The data indicate that, indeed, predictions of hearts-of-palm were relatively accurate and should be useful in estimating yields nondestructively.

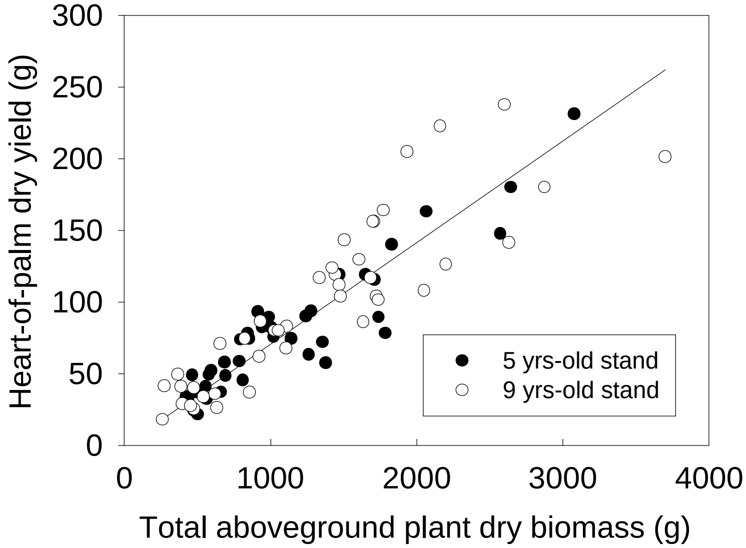

Figure 6. Relationship between total aboveground shoot biomass (SB) and heart-of-palm yields (Y) for two peach palm stands at 'Los Diamantes' Experimental Station, Costa Rica (Y = 0.0718 SB, RMS = 24, R^2_{adj} = 0.95, n=81.

<u>Growth and nutritional response of peach palm to P additions</u> - The experiment started on August 1999 in Altamira, Costa Rica, and described in the Year 1999 report, proceeded as scheduled during the year 2000. One-year heart of palm yields did not respond to P additions although soil levels were initially low. Foliar P levels, however, were all above proposed sufficiency levels of 0.23% for young leaves and 0.16 % for old leaves. The fertilization strategy was changed during the second year by adding the annual P doses in one application. Recent sampling indicated a relatively large gradient in soil P (from about 4 to 30 mgP/g) between the control and the high-P level but this variation does not concur with foliar P levels. Also, recent data indicated that the peach palm stand appears to show some response in yield to P additions.

In Brazil, responses to P additions were observed in experiments for heart-of-palm, however, neither foliar P (young and old leaves) nor soil P at 0-5 and 5-20 cm depths) were able to predict that a yield response would occur. For fruit production in Brazil, plants did not respond to P additions above 20 kg/ha where P foliar contents were above the proposed critical levels.

<u>Additional diagnostic criteria for P deficiency in peach palm</u> - Results so far indicate that whole-plant characteristics would be more useful than tissue features to characterize P deficiencies in peach palm. Soil and plant P analysis did not adequately diagnose plant P status and predict responses to P additions in peach palm. Tissue nutrient analysis on peach palm stands in Costa Rica with soil P ranging from about 7 to 40 mgP/g indicated that petiole P showed the largest variation in P concentration while foliar P exhibited the smallest change. The variation was intermediate for coarse roots and plant bases ("spider").

Additional testing should be conducted in trials where response to P additions was already detected such as the case of the Amazon region.

2. *Mali*

Inorganic and organic mixtures of fertilizer materials - (Mamadou D. Doumbia, Aminata Sidibe, Adama Bagayoko, Mamadou A. Diarra, Hamidou Konare, Adama Coulibaly, Birama S. Coulibaly, Diakalia Sogodogo, Zoumana Kouyate of IER with support from Richard Kablan and Russell Yost)

a. *Calibration of P Buffer Coefficients* - Laboratory incubation studies were conducted to calibrate P buffer coefficients predicted by the PDSS component of NuMaSS using selected soils of Mali . These samples were first analyzed for clay content and Bray-1 P. These data were used by PDSS to predict buffer coefficients referred to as a_{2m}. These soil samples were then incubated to estimate buffer coefficient referred to as a_{2i}. Then, a_{2m} and a_{2i} were compared. Selected data from this study is shown in Table 9.

Table 9. Clay content and P buffer coefficients of selected soils of Mali.

		P Buffer Coefficient (a_2)		
Treatments	**Clay**	**Lab Incubation**	**NuMaSS**	**Mean**
	%			
SOILS				
Cinzana summit	5.2	0.78	0.85	0.81a
Cinzana J11	18.2	0.52	0.54	0.53c
Macina - Moursi1	59.9	0.15	0.14	0.14g
Macina - Moursi2	53.8	0.19	0.17	0.17gf
Seno	4.7	0.82	0.51	0.66b
Selingue1	24.2	0.78	0.49	0.63b
Selingue2	3.6	0.14	0.89	0.50c
Dougouba	3.4	0.77	0.89	0.83a
Doubouba2	2.8	0.80	0.91	0.87a
Macina - Danga1	27.5	0.08	0.40	0.24f
Macina - Danga2	34.4	0.08	0.32	0.20f
Sdt1 Moursi	32.7	0.47	0.27	0.37c
Sdt2 Danga	24.5	0.60	0.45	0.52c
Sdt3 Danga	29.5	0.51	0.38	0.45d
Sdt4 Molodo	31.9	0.32	0.35	0.33e
METHODS				
Lab Incubation (a_{2i})				0.47b
NuMaSS (a_{2m})				0.50a
Interaction (SxM)				S
CV (%)				12

The correspondence between the laboratory incubation and predicted values is remarkable and suggests that the buffer coefficient approach has wide applicability and likely will be useful for initial predictions of P requirements for many regions in West Africa where prior soil testing has been difficult.

b. *Placement of Mineral and Organic Fertilizers*

1. Placement of mineral fertilizer -

Table 10. Sorghum yield as influenced by methods of mineral fertilizer application.

Treatment	Harvested Plants	Plant Height at Harvest	Sorghum Yield Head	Grain	Stalk
	no. /ha	m	---------- kg ha^{-1} ----------		
Check	39445a	2.27b	860b	490a	2940a
1:1 Seed-fertilizer Mix	25000a	2.41a	1370ab	930a	2890a
Seed & fertilizer same hill	25000a	2.28a	840b	600a	2500a
Conventional application	31667a	2.46a	1620a	990a	2100a
CV (%)	29	2	27	44	46

2. Placement of organic amendments -

Table 11. Sorghum yield as influenced by methods of manure application.

Treatment	Harvested Plants	Plant Height at Harvest	Sorghum Yield Head	Grain	Stalk
	no. /ha	m	---------- kg ha^{-1} ----------		
Check	19506a	2.30a	790b	600b	3090a
Plowing under	34321a	2.50a	1320a	940a	3940a
Surface placement	34691a	2.50a	900b	750ab	3930a
CV (%)	25	2	16	13	23

3. “Manure Extender” Studies - These studies involved both factorial combinations and substitutions of mineral and organic sources of nutrients. The impacts of these were evaluated on sorghum yield and soil properties.

Substitution Experiment An experiment involving substitutions of organic and mineral sources of P was planted at the Sotuba experiment station. The total P to provide was that contained in 100 kg DAP (20%)) and 5000 kg of manure (0.56%). Ratios tested were 100:0, 75:25, 50:50; 25:75, 0:100 and a check.

Table 12. Sorghum yield as influenced by substitutions of organic and mineral sources of P.

Treatment	Harvested Plants	Plant Height at Harvest	Sorghum Yield Head	Grain	Stalk
	no. /ha	m	---------- kg ha^{-1} ----------		
100:0	1.92ab	42084a	1540a	1292a	2916a
75:25	1.96a	28125ab	1380a	979b	2292ab
50:50	1.86ab	26042b	1020b	792bc	1876bc
25:75	1.74ab	39167ab	1330a	917b	1875bc
0:100	1.69b	24167b	810b	708cd	1458c
Check	1.79ab	27500ab	980b	521d	1459c
CV (%)	9	29	17	15	24

Combination Experiment A 4 x 3 factorial combination experiment was implemented at the Sotuba experiment station.

Table 13. Sorghum yield as influenced by combination of mineral and organic sources of nutrients.

Treatment	Harvested Plants	Plant Height at Harvest	Sorghum Yield Head	Grain	Stalk
	no. /ha	m	---------- kg ha^{-1} ----------		
ORGANIC SOURCE (kg ha^{-1})					
0	32222a	1.61a	1220a	430a	1430a
1250	32570a	1.66a	640b	670ab	1560a
2500	73429a	1.67a	900ab	770a	1570a
5000	25926a	1.69a	1130a	890a	1570a
MINERAL SOURCE					
0	32500a	1.63a	750a	460b	1460a
Unique R	33750a	1.68a	1090a	720a	1610a
2x Unique R	56947a	1.69a	1930a	770a	1490a
Interaction Org x Miner	NS	NS	NS	NS	NS
CV (%)	60	9	42	39	41

In the case of organic amendments it appears that plowing the organic material into the soil may be more beneficial than surface placement, a not too surprising result. Of particular interest where organic fertilizer was applied was the greater head weights, which may have been a result of better nutrient conditions during head filling than during formation of the number of heads.

The results here presented indicate no significant difference in yields among the various types of fertilizer placement. This appears to be, in part, due to unusually high variability (CV = 44%). The sister block of this experiment was far less variable (CV = 12%), and less differences between treatments were significant.

'Manure extender' results indicated less effectiveness of organic manures alone, particularly when added alone. The number of plants in the differing treatments was very large and may have been a factor in the greater yields where inorganic manures alone were used.

In the case of the combination experiments it is very difficult to infer meaningful conclusions from only yield data. Analyses of soils and plant tissues are integral parts of such research because they often provide an explanation for the effects. For example, it appears from the check plot that the initial soil levels of nutrients were relatively high, making it very difficult for the experiment to detect any effects.

Completion of year-3 mid-term socio-economic assessment (Mamadou Doumbia, Adama Coulibaly, Oumar Coulibaly, Lloyd Hossner, Frank Hons, Jot Smyth and Frank Smith) - during this year, all data was collected and the mid-term report was finalized. During the baseline survey in year 1, 16% of farmers in the Cinzana area reported use of 15-15-15 fertilizer and 9% reported use of urea in millet production. These results were inconsistent with local researcher experience and the unfavorable price ratios between millet and fertilizers. Table 14 shows that millet farmers using fertilizers were distributed among sampled villages, and included both landowners and farmers using land of others. Their production areas ranged from 4 to 24 ha and several application rates and methods are reported. Fertilizers were usually applied to "hot spots" (areas of pronounced nutrient and/or water deficit), instead of uniform applications to all the land cropped to millet. Farmers explained the need to invest in fertilizers to (1) compensate for farmyard manure shortages, (2) poor nutrient quality of the manures, or (3) improve yield of late plantings. Farmers using chemical fertilizers also used manures, insecticides and intercropping practices (Table 15). A survey of 1999 commodity prices in the Cinzana area revealed that millet and sorghum prices were considerably lower than the national average producer prices (latest national data was for 1998). Cinzana region and national average prices were 50 and 105 CFA/kg for millet, and 60 and 98 CFA/kg for sorghum.

Seasonal changes in prices of inputs and crops were also summarized for the Cinzana area (Table 16). While fertilizer prices are stable throughout the year, labor costs are highest during the season of land preparation. The variation in millet prices by 50% accounts for farmer efforts to store this staple for future consumption and sale.

Table 14. Descriptive information on the subset of millet farmers using chemical fertilizers.

Farmer	Village	Land Tenure	Land Area	Fertilizer Type	Fertilizer Dose*	Fertilizer Method	Supplementary Dose	Supplementary Method
			ha		kg ha^{-1}		kg ha^{-1}	
1	Dilaba	Landowner	10.00	CC	100	localized	0	0
2	Dougouba	Exploitant	10.00				75	broadcast
3	Dougouba	Landowner	5.00	CC	75	localized	25	localized
4	Cinzana-Village	Landowner	4.00	CC	50	broadcast	0	0
5	Cinzana-Village	Landowner	12.00	CC	100	broadcast	0	0
6	Konogola	Landowner	6.50	CC	100	localized	0	0
7	Konogola	Landowner	12.50	CC	100	localized	0	0
8	Cinzana-Gare	Exploitant	6.00	CC	50	broadcast	0	0
9	Konogola	Exploitant	24.00	CC	50	localized	50	localized
10	Konogola	Exploitant	6.00	CC	100	broadcast	50	broadcast

*Fertilizer dose was reported by farmers as the number of 50 kg bags used per ha. However, the application treatment of "hot spots" or larger areas where, for example, the planting was late. Therefore, the dose rate should not be interpreted as uniform across the production area. CC= cereal complex fertilizer, 15-15-15.

Table 15. Organic matter, other inputs and intercropping practices within the subset of farmers using chemical fertilizers.

Farmer	Village	Organic Inputs	Organic Dose	Organic Method	Other Inputs	Inter-cropping
			kg ha^{-1}			
1	Dilaba	manure	96	placement	seed treatment	cowpea
2	Dougouba	manure	?	placement	seed treatment	cowpea
3	Dougouba	manure	15	placement	insecticides	cowpea
4	Cinzana-Village	manure	15	broadcast	seed treatment	cowpea
5	Cinzana-Village	manure	30	broadcast	seed treatment	cowpea
6	Konogola	manure	50	broadcast	seed treatment	cowpea
7	Konogola	manure	50	broadcast	seed treatment	cowpea
8	Cinzana-Gare	manure	10	broadcast	seed treatment	pulse
9	Konogola	manure	25	broadcast	seed treatment	pulse
10	Konogola	manure	50	broadcast	seed treatment	cowpea

Table 16. Change in the price in the Cinzana area during the 1999 growing season.

Input or Crop	May – July (pre-season)	Aug. – Oct. (pre-harvest)	Dec. – Jan. (harvest)	Feb. - April (post harvest)
	------------------------------ F CFA ------------------------------			
Farm labor (day^{-1})	1000	850	800	750
Fertilizers (kg^{-1})				
Urea (46-0-00)*	200	200	200	200
DAP (18-46-0)*	220	220	220	220
Cereal blend (15-15-15)*	200	200	200	200
Crops (kg^{-1})				
Millet	70	100	50	60
Sorghum	80	110	60	70
Peanut	300	400	150	200
Cowpea	350	400	200	250

* (% N – P_2O_5 – K_2O)

On-farm evaluation of NuMaSS soil nutrient diagnosis and recommendations - (Mamadou Doumbia, Aminata Sidibe, Adama Bagayoko, Mamadou Diarra, Hamidou Konare, Adama Coulibaly, Birama Coulibaly, Diakalia Sogodogo, and Zoumana Kouyate of IER and Lloyd Hossner, Frank Hons, and Anthony Juo of Texas A&M University)On-farm studies were conducted to test the recommendations from NuMaSS against a control, the standard fertilizer recommendation of Mali (Unique R) and the 4-quadrant method suggested by van Duivenbooden et al. (1966) (Quadrant R). These tests were implemented at the Sotuba Research Station for both sorghum and maize, at Cinzana for millet and sorghum, and at Dougouba for millet. Samples were collected from experimental units for laboratory characterization (Gee and Bauder, 1986; Sparks et al., 1996) and for prediction of fertilizer application rates by the NuMaSS model. Recommendations from Quadrant R are based on nutrient uptake (N, P, and K) for yield target (van Duivenbooden et al., 1996). These uptake rates were multiplied by efficiency factors to derive the Quadrant R application rates. Applications rates of N, P, K, and lime for the different treatments are indicated in Table 17.

Table 17. Fertilizer application rates for the different recommendation methods.

	DAP		Urea		K_2SO_4		Lime	
Method	Maize	Sorghum	Maize	Sorghum	Maize	Sorghum	Maize	Sorghum
	------------------------------ $kg\ ha^{-1}$ ------------------------------							
Control	0	0	0	0	0	0	0	0
Quadrant R	256	65	466	204	488	80	0	0
NuMaSS	202	149	378	233	0	0	750	1800
Unique R	100	100	150	50	0	0	0	0

1. *Sorghum* - yields obtained with various fertilizer recommendations were normally higher than that of the control (Table 18). The national recommendation in Mali (Unique R) should have produced a lower yield than the other two recommendation methods because of the higher rates of nutrients recommended by both models. In addition to higher rates of N and P, NuMaSS has recommendations for lime while Quadrant R includes K. Despite a strong positive trend in plant height, head yield, and stalks yield, recommendations from NuMaSS did not yield significantly higher sorghum grain. In fact, higher rates of DAP and Urea recommended by NuMaSS (Table 17) should have resulted in a grain yield increase.

Table 18. Sorghum yield as influenced rates of N, P, K and lime as predicted by various fertilizer recommendation systems.

	Plant		**Yield**		
Treatment	**Density**	**Height**	**Head**	**Grain**	**Stalk**
	no./ha	cm	---------- kg ha^{-1} ----------		
Control	20741b	152b	1296a	680b	2333b
Quadrant R	28148ab	178a	1745a	1162a	5222a
NuMaSS	30370ab	190a	1869a	1397a	3074ab
Unique R	36296a	186a	1775a	1259a	3037ab
CV (%)	20	7	19	14	33

2. *Maize* - The erratic rainy season did not allow maize to mature properly at Sotuba, leading to very low and non significant differences in grain yield (Table 19). Plant height and stalk yield indicated differences due to fertilizer applications. The high variability associated with the data apparently masked a significant separation of treatment means.

Literature Cited -

Van Duivenbooden, N., C.T. DeWit, and H. Van Keulen.1996. Nitrogen, phosphorus, and potassium relations in five major cereals reviewed in respect to fertilizer recommendations using simulation modeling. Fertilizer Research. 44:37-49.

<u>Cowpea and millet yield response and interactions among N, P, and lime rates</u> - (Mamadou Doumbia, Aminata Sidibe, Adama Bagayoko, Mamadou Diarra, Hamidou Konare, Adama Coulibaly, Birama Coulibaly, Diakalia Sogodogo, and Zoumana Kouyate of IER, and Lloyd Hossner, Frank Hons and Anthony Juo of Texas A&M University and Daniel Israel of North Carolina State University) The objective of the experiment was to test predictions for N, P and lime for millet and cowpea on sandy Alfisols of the African Sahel using the NuMaSS model and to identify necessary refinements to the model. The treatments in both cowpea and millet experiments were not implemented as planned. In the "millet core experiment" N rates were not established for the millet crop in 1998; therefore, N for crop growth was derived from soil N reserves. The lack of optimum N supply probably had an impact on yield response to applied P and lime. The P variable in both the "cowpea and millet core experiments" was eliminated when P level in all plots was erroneously adjusted to100% of the amount recommended by NuMASS before the 1999 cropping season. Therefore,

Table 19. Maize yield as influenced rates of N, P, K and lime as predicted by various fertilizer recommendation systems.

	Plant		Yield		
Treatment	**Density**	**Height**	**Head**	**Grain**	**Stalk**
	no./ha	cm	---------- kg ha^{-1} ----------		
			Recommendations		
Control	64075a	111b	111b	131a	2519c
Quadrant R	67038a	161a	3092a	449a	8519a
NuMaSS	67038a	162a	1926ab	403a	6296b
Unique R	70371a	163a	1407b	440a	10222a
			Varieties		
Sotubaka	65741a	150a	2389	450a	7630
Dembany uma	68334a	149a	1404b	273a	6148b
Interaction	NS	NS	NS	NS	NS
CV (%)	12	16	56	108	23

response of various crop parameters to P could not be evaluated for the 1999 cropping season. Lime was not applied before the 1999 cropping season for either core experiment as soil pH values were at desirable levels in the respective lime treatments.

Chemical analysis of soil and plant samples were conducted by personnel at the Soil and Plant Analysis Lab (LaboSEP) at the Sotuba Station In Bamako, Mali. Chemical properties of soils for both experiments were evaluated before establishment of treatments (Tables 20 and 21). Bray I P level in soils for both core experiments was 11 mg/kg in the top 7.5 cm and decreased significantly in the 7.5 to 22.5 cm depth to 6 mg/kg. Soil pH decreased and exchangeable acidity increased with depth. Exchangeable Ca increased significantly with depth which is typical of Alfisols. Exchangeable K and Mg were relatively constant with depth.

1. *Influence of P and Lime on Yield and Biomass Production of Crops* - In the 1998 season of the “cowpea core experiment “ (Table 22), P and lime treatments had no significant effect on grain, stover and total yields of the cowpea crop, however, coefficients of variation for these parameters were very high (25 to 42%). In the 1999 season grain, stover and total yields of the millet crop were not significantly affected by lime application (Table 22). Leaving the cowpea residue on the plots (N0P2L2b) after the 1998 season did not enhance grain and total yields of the subsequent millet crop in 1999. It is also evident that application of fertilizer N to the 1999 millet crop did not increase the yield significantly when adequate P and lime was applied. This implies a substantial amount of N was added to the soil by the 1998 cowpea crop from roots, nodules and leaf and petiole litter that fell from the cowpea plants during seed fill. Lack of P response in the 1999 millet crop was caused by elimination of the P

variable by application of P to all plots to increase the P level to 100% of the NuMASS recommendation.

Table 20. Chemical properties of the Haplustalfs soil at Cinzana Research Station before planting the "millet core experiment" in 1998. Since samples were taken before establishment of treatments, only the effect of sampling depth is illustrated.

Chemical property	**Sampling depth**				
	0 - 7.5 cm	**7.5-22.5 cm**	**22.5-45 cm**	**45 - 75 cm**	**$LSD_{0.05}$**
Bray 1 P, mg/kg	11.0	5.5	---	---	1.2
pH in H_2O	5.6	4.8	4.6	4.7	0.22
Exch. acidity, cMole/kg	0.49	0.44	0.65	0.60	0.11
Exch..Ca, cMole/kg	0.18	0.30	0.34	0.51	0.24
Exch. Mg, cMole/kg	0.16	0.11	0.24	0.23	0.04
Exch. K, cMole/kg	0.20	0.08	0.08	0.09	0.03
ECEC, cMole/kg	1.03	0.94	1.32	1.43	0.24
carbon %	0.36	---	---	---	—

Table 21. Chemical properties of the Haplustalfs soil at the Cinzana Research Station before planting cowpea in the "cowpea core experiment" in 1998. Since samples were taken before establishment of treatments, only the effect of sampling depth is illustrated.

Chemical property	**Sampling depth**				
	0 - 7.5 cm	**7.5-22.5 cm**	**22.5-45 cm**	**45 - 75 cm**	**$LSD_{0.05}$**
Bray 1 P, mg/kg	11.8	6.6	---	---	1.4
pH in H_2O	5.4	4.7	4.7	4.5	0.1
Exch. acidity, cMole/kg	0.62	0.60	---	---	0.15
Exch..Ca, cMole/kg	0.29	0.76	0.78	0.69	0.11
Exch. Mg, cMole/kg	0.26	0.31	0.41	0.50	0.04
Exch. K, cMole/kg	0.18	0.12	0.10	0.09	0.02
ECEC, cMole/kg	1.37	1.79	---	---	0.16
carbon %	0.23	---	---	---	—

In the 1998 season of the "millet core experiment", the high P and high lime (N0P2L2) significantly increased millet grain yield even though the crop did not receive any fertilizer N (Table 23). This indicates soil reserves of N provided sufficient N to allow response to lime and P application. Lime and P application had no significant effect on stover and total yield. Apparently, improved nutrition from lime and P application enhanced assimilate accumulation in grain at the expense of vegetative plant parts. In the 1999 season, the previous lime and P treatments had no significant effect on grain, stover and total yields of the cowpea crop (Table 23). The lack of P response in the 1999 cowpea crop was caused by elimination of the P variable by inappropriate application of P to all plots. Inoculation of cowpea with a mixture of Bradyrhizobium strains from Zimbabwe (N0P2L2)did not increase seed or total biomass yields compared to the control (N0P2L0). Apparently, the indigenous strains had sufficient nitrogen fixation to support N requirements for yield levels under these soil and environmental conditions.

Table 22. Cowpea grain, stover and total yield in the 1998 season and subsequent millet grain, stover and total yield in the 1999 season as influenced by lime, N and P treatments in the "cowpea core experiment".

----------- Cowpea - 1998 Season -----------				------------ Millet - 1999 Season -------------			
Treat-ments	**Grain yield**	**Stover yield**	**Total yield**	**Treat-ments**	**Grain yield**	**Stover yield**	**Total yield**
	---------------- kg/ha ----------------				--------------- kg/ha ----------------		
N0P0L0[a]	646	1012	1658	N0P2L0	1204	3175	4378
N0P0L2	563	1296	1859	N2P2L2	1574	4233	5807
N0P1L2	605	1642	2246	N2P2L2	1491	3703	5194
N0P2L2	745	2432	3178	N2P2L2	1693	4021	5714
N0P2L0	776	2247	3024	N2P2L0	1643	4629	6272
N0P2L1	658	1568	2226	N2P2L1	1600	4286	5885
N0P1L1	573	1481	2054	N2P2L1	1627	3836	5462
N0P2L2	678	1753	2432	N0P2L2	1481	3637	5119
N0P2L2	790	1716	2506	N1P2L2	1561	3862	5423
N0P2L2[b]	1128	1852	2980	N0P2L2[b]	1878	4456	6336
N0P1L1	557	1481	2039	N1P2L1	1336	3240	4577
$LSD_{0.05}$	NS	NS	NS		NS	NS	NS
CV %	42.2	29.1	24.7		17.2	20.0	17.7

[a] Level 0 = no application of N, P or lime; Level 1 = 50% of amount recommended by NuMaSS; Level 2 = 100% of amounts recommended by NuMaSS; during 1999 season soil P was erroneously adjusted to level 2 in all treatments. Lime was only applied prior to planting in 1998 season. Fertilizer N was not applied to the selected cowpea treatments as originally planned.

[b] The only treatment where cowpea stover was left as residue in the field.

2. *Influence of Lime and P Application on Crop N and P Accumulation* - In the "cowpea core experiment", P and lime treatments had no significant effects on N accumulation in grain, and stover of the 1998 cowpea crop or in grain and stover of the subsequent 1999 millet crop

(Table 24). The lack of measurable response to treatments in the cowpea crop was associated with high plot to plot variation in yield parameters (cv 's ranged from 26 to 49%). The millet crop in 1999 also had large plot to plot variability (cv's ranged from 22 to 34%) (Table 24). Inappropriate P applications in 1999 eliminated the P variable for the millet crop. The overall grain, stover and total N accumulation means for the 1998 cowpea crop were 30, 35 and 65 kg N/ha, respectively. The overall grain, stover and total N accumulation means for the 1999 millet crop were 22, 27 and 49 kg N/ha.

Table 23. Millet grain, stover and total yield in the 1998 season and subsequent cowpea grain, stover and total yield in the 1999 season as influenced by lime, N and P treatments in the "millet core experiment".

-----------Millet - 1998 Season -----------				------------ Cowpea - 1999 Season -------------			
Treat-ments	**Grain yield**	**Stover yield**	**Total yield**	**Treat-ments**	**Grain yield**	**Stover yield**	**Total yield**
	---------------- kg/ha ----------------				--------------- kg/ha ----------------		
N0P0L0[a]	1208	3194	4402	N0P2L0	491	1506	1997
N0P0L2	1541	3483	5025	N0P2L2	376	1246	1623
N0P1L2	1522	3847	5370	N0P2L2	503	1062	1565
N0P2L2	2310	3842	6152	N0P2L2	404	1852	2256
N0P2L0	1476	4293	5770	N0P2L0	367	1358	1725
N0P2L1	1977	4000	5976	N0P2L1	426	1741	2167
N0P1L1	1546	4316	5863	N0P2L1	416	1420	1836
N0P2L2	1824	4004	5828	N2P2L2	417	1728	2145
N0P2L2	1884	4189	6073	N0P2L2[b]	315	1408	1723
N0P1L1	1518	3633	5152	N1P2L1	355	1481	1836
$LSD_{0.05}$	511	NS	NS		NS	NS	NS
CV %	17.7	19.1	16.1		21.3	35.2	28.3

[a] Level 0 = no application of N, P or lime; Level 1 = 50% of amount recommended by NuMaSS; Level 2 = 100% of amounts recommended by NuMaSS; during 1999 season soil P was erroneously adjusted to level 2 in all treatments. Lime was only applied prior to planting in 1998 season.

[b] The only treatment inoculated with a mixture of two efficient Bradyrhizobium strains from Zimbabwe when planted to cowpea.

In the "millet core experiment", high P (P2) coupled with either lime rate (L1,L2) significantly increased N accumulation in the grain of the 1998 millet crop relative to the control (N0P0L0), but did not increase stover or total N accumulation (Table 25). Grain, stover and total N accumulation by the subsequent cowpea crop in 1999 was not significantly affected by lime. Application of N to the 1999 cowpea crop (N2P2L2) did not increase N accumulation. Apparently, N fixation capacity was not a factor limiting cowpea growth and yields. The P variable was eliminated by inappropriate application of P. Overall means for grain, stover and total N accumulation by the 1998 millet crop were 22,15 and 37kg N/ha, respectively. Overall means for grain, stover and total N accumulation by the 1999 cowpea crop were 13, 32 and 47 kg N/ha, respectively.

Table 24. Cowpea grain, stover and total N in the 1998 season and subsequent millet grain, stover and total N in the 1999 season as influenced by lime, N and P treatments in the "cowpea core experiment".

----------- Cowpea - 1998 Season -----------				------------ Millet - 1999 Season -------------			
Treat-ments	Grain N	Stover N	Total N	Treat-ments	Grain N	Stover N	Total N
	---------------- kg/ha ----------------				--------------- kg/ha ----------------		
N0P0L0[a]	24.7	20.3	45.3	N0P2L0	15.8	17.4	33.2
N0P0L2	22.3	27.3	50.3	N2P2L2	24.8	30.7	55.5
N0P1L2	25.0	38.7	63.3	N2P2L2	23.4	28.5	52.0
N0P2L2	31.7	45.7	78.3	N2P2L2	22.4	24.2	46.7
N0P2L0	35.3	46.7	81.7	N2P2L0	24.8	34.1	58.9
N0P2L1	29.3	35.0	64.0	N2P2L1	25.6	32.7	58.3
N0P1L1	27.3	29.7	57.0	N2P2L1	24.6	27.7	52.3
N0P2L2	29.3	37.3	66.7	N0P2L2	19.2	22.5	41.7
N0P2L2	30.7	34.0	64.7	N1P2L2	21.2	22.5	43.7
N0P2L2[b]	54.7	35.7	90.7	N0P2L2[b]	24.6	27.7	52.3
N0P1L1	21.3	29.3	50.7	N1P2L1	19.7	25.0	44.7
$LSD_{0.05}$	NS	NS	NS		NS	NS	NS
CV %	49.5	37.1	25.8		21.9	34.3	25.9

[a] Level 0 = no application of N, P or lime; Level 1 = 50% of amount recommended by NuMaSS; Level 2 = 100% of amounts recommended by NuMaSS; during 1999 season soil P was erroneously adjusted to level 2 in all treatments. Lime was only applied prior to planting in 1998 season. Fertilizer N was not applied to the selected cowpea treatments as originally planned.

[b] The only treatment where cowpea stover was left as residue in the field.

Inferences about the amount of N fixed symbiotically by the cowpea crop can be derived from comparisons of total N accumulated in the 1998 millet crop of the "millet core experiment" and the 1998 cowpea crop of the "cowpea core experiment". These experiments were initiated on different parts of the same field that had been in fallow for several years. Since the millet crop did not receive the planned N application, N accumulation in the crop is a measure of residual N in the soil. As a result subtraction of total N accumulated by the millet crop from total N accumulated by the cowpea crop provides a reasonable estimate of the amount of N fixed by the cowpea crop. The overall mean for total N accumulated by the 1998 millet crop is 37 kg N/ha and the overall mean for total N accumulation in the 1998 cowpea crop is 65 kg N/ha (derived from Tables 24 and 25). Therefore, N difference indicates that the 1998 cowpea crop derived 28 kg N/ha or 43% of its N from symbiotic nitrogen fixation. Such comparisons are not feasible with the 1999 crops because the cowpea crop followed a millet crop that would have depleted soil N reserves because it did not receive N fertilizer.

Table 25. Millet grain, stover and total N in the 1998 season and subsequent cowpea grain, stover and total N in the 1999 season as influenced by lime, N and P treatments in the "millet core experiment".

-----------Millet - 1998 Season -----------				------------ Cowpea - 1999 Season -------------			
Treat-ments	**Grain N**	**Stover N**	**Total N**	**Treat-ments**	**Grain N**	**Stover N**	**Total N**
	---------------- kg/ha ----------------				--------------- kg/ha ----------------		
N0P0L0[a]	16.7	12.7	29.4	N0P2L0	16.3	33.3	49.6
N0P0L2	20.3	11.7	32.0	N0P2L2	12.0	26.0	38.0
N0P1L2	21.7	11.3	33.0	N0P2L2	16.3	23.0	39.3
N0P2L2	30.7	15.3	46.0	N0P2L2	13.3	39.7	53.0
N0P2L0	19.3	16.0	35.3	N0P2L0	11.7	30.0	41.7
N0P2L1	27.0	14.3	41.3	N0P2L1	13.7	34.0	47.7
N0P1L1	21.0	17.0	38.0	N0P2L1	13.7	30.0	43.7
N0P2L2	23.3	12.3	35.6	N2P2L2	13.7	37.0	50.7
N0P2L2	24.3	22.0	46.3	N0P2L2[b]	10.3	30.7	41.0
N0P1L1	19.3	14.3	33.6	N1P2L1	11.3	30.7	42.0
$LSD_{0.05}$	7.5	NS	NS		NS	NS	NS
CV %	19.6	33.2	19.8		22.2	38.1	27.8

[a] Level 0 = no application of N, P or lime; Level 1 = 50% of amount recommended by NuMaSS; Level 2 = 100% of amounts recommended by NuMaSS; during 1999 season soil P was erroneously adjusted to level 2 in all treatments. Lime was only applied prior to planting in 1998 season.

[b] The only treatment inoculated with a mixture of two efficient Bradyrhizobium strains from Zimbabwe when planted to cowpea

The P and lime treatments did not influence P accumulation in the crops of the "cowpea core experiment" (Table 26). The high P level significantly increased total P accumulation by the millet crop in the "millet core experiment" but not significantly increase P accumulation by the cowpea crop (Table 27).

The influence of P and lime treatments on N and P concentrations in cowpea and millet crops of the cowpea and millet core experiments is illustrated in Tables 28 and 29. Lime and P treatments had no significant effect on N or P concentrations in tissues of cowpea and millet crops in either core experiment. The N concentrations in grain of the 1998 cowpea crop was 25% higher than that of the 1999 cowpea crop There is no obvious explanation for the difference.

Table 26. Cowpea grain, stover and total P in the 1998 season and subsequent millet grain, stover and total P in the 1999 season as influenced by lime, N and P treatments in the "cowpea core experiment".

---------- Cowpea - 1998 Season ----------				----------- Millet - 1999 Season ------------			
Treat-ments	**Grain P**	**Stover P**	**Total P**	**Treat-ments**	**Grain P**	**Stover P**	**Total P**
	--------------- kg/ha ---------------				-------------- kg/ha ---------------		
N0P0L0[a]	2.6	1.7	4.2	N0P2L0	3.6	1.9	5.5
N0P0L2	2.3	2.5	4.8	N2P2L2	4.8	1.8	6.6
N0P1L2	2.8	3.5	6.3	N2P2L2	4.7	2.2	7.0
N0P2L2	3.9	4.7	8.6	N2P2L2	5.4	4.0	9.4
N0P2L0	4.3	4.5	8.8	N2P2L0	5.2	3.0	8.2
N0P2L1	3.2	3.0	6.1	N2P2L1	4.9	3.1	7.9
N0P1L1	3.0	2.5	5.4	N2P2L1	4.9	2.7	7.6
N0P2L2	3.5	3.7	7.2	N0P2L2	5.0	3.1	8.1
N0P2L2	4.0	3.3	7.2	N1P2L2	5.2	3.2	8.4
N0P2L2[b]	5.9	3.2	9.1	N0P2L2[b]	5.9	4.1	10.0
N0P1L1	2.6	2.8	5.4	N1P2L1	4.2	1.9	6.1
$LSD_{0.05}$	NS	NS	NS		NS	NS	NS
CV %	48.4	39.1	29.1		31.8	42.9	24.1

[a] Level 0 = no application of N, P or lime; Level 1 = 50% of amount recommended by NuMaSS; Level 2 = 100% of amounts recommended by NuMaSS; during 1999 season soil P was erroneously adjusted to level 2 in all treatments. Lime was only applied prior to planting in 1998 season. Fertilizer N was not applied to the selected cowpea treatments as originally planned.

[b] The only treatment where cowpea stover was left as residue in the field.

Table 27. Millet grain, stover and total P in the 1998 season and subsequent cowpea grain, stover and total P in the 1999 season as influenced by lime, N and P treatments in the “millet core experiment”.

-----------Millet - 1998 Season -----------				------------ Cowpea - 1999 Season -------------			
Treat-ments	**Grain P**	**Stover P**	**Total P**	**Treat-ments**	**Grain P**	**Stover P**	**Total P**
	---------------- kg/ha ----------------				--------------- kg/ha ----------------		
N0P0L0[a]	3.4	2.0	5.4	N0P2L0	2.2	3.8	6.0
N0P0L2	4.9	1.4	6.3	N0P2L2	1.8	3.8	5.6
N0P1L2	4.5	1.8	6.3	N0P2L2	2.3	3.2	5.5
N0P2L2	7.0	3.2	10.2	N0P2L2	2.0	5.5	7.5
N0P2L0	4.4	2.3	6.7	N0P2L0	1.6	3.5	5.1
N0P2L1	6.2	2.7	8.9	N0P2L1	2.0	4.8	6.8
N0P1L1	4.5	4.0	8.5	N0P2L1	2.0	4.1	6.1
N0P2L2	5.6	2.5	8.1	N2P2L2	2.0	6.1	8.1
N0P2L2	9.0	3.5	12.6	N0P2L2[b]	1.6	5.2	6.8
N0P1L1	4.7	2.5	7.2	N1P2L1	1.6	4.0	5.6
$LSD_{0.05}$	NS	NS	4.2		NS	NS	NS
CV %	35.3	46.1	30.3		22.4	38.5	28.7

[a] Level 0 = no application of N, P or lime; Level 1 = 50% of amount recommended by NuMaSS; Level 2 = 100% of amounts recommended by NuMaSS; during 1999 season soil P was erroneously adjusted to level 2 in all treatments. Lime was only applied prior to planting in 1998 season.

[b] The only treatment inoculated with a mixture of two efficient Bradyrhizobium strains from Zimbabwe when planted to cowpea

Table 28. Cowpea grain and stover N and P concentration in the 1998 season and subsequent millet grain and stover N and P concentration in the 1999 season as influenced by lime, N and P treatments in the "cowpea core experiment".

-----------------Cowpea - 1998 Season -----------------					**--------------------- Millet - 1999 Season ------------------**				
Treat-ments	**Grain N conc.**	**Grain P conc.**	**Stover N conc.**	**Stover P conc.**	**Treat-ments**	**Grain N conc.**	**Grain P conc.**	**Stover N conc.**	**Stover P conc.**
	--------------- % of dry wt. ---------------					----------------- % of dry wt. ---------------			
N0P0L0a	3.89	0.40	1.98	0.16	N0P2L0	1.32	0.30	0.56	0.06
N0P0L2	4.00	.041	2.30	0.20	N2P2L2	1.58	0.30	0.74	0.04
N0P1L2	4.06	0.46	2.35	0.22	N2P2L2	1.57	0.32	0.76	0.06
N0P2L2	4.23	0.51	1.89	0.19	N2P2L2	1.32	0.32	0.60	0.10
N0P2L0	4.37	0.53	2.02	0.19	N2P2L0	1.51	0.31	0.73	0.06
N0P2L1	4.60	0.49	2.22	0.18	N2P2L1	1.60	0.30	0.78	0.07
N0P1L1	4.51	0.49	2.05	0.17	N2P2L1	1.50	0.30	0.70	0.07
N0P2L2	4.13	0.50	2.10	0.21	N0P2L2	1.30	0.34	0.66	0.09
N0P2L2	3.87	0.51	2.00	0.19	N1P2L2	1.35	0.34	0.57	0.08
N0P2L2b	4.95	0.53	1.90	0.16	N0P2L2b	1.32	0.31	0.68	0.09
N0P1L1	3.89	0.45	1.99	0.19	N1P2L1	1.45	0.31	0.74	0.06
LSD0.05	NS	NS	NS	NS		NS	NS	NS	NS
CV %	15.3	11.7	19.9	23.7		10.8	7.7	35.9	38.3

a Level 0 = no application of N, P or lime; Level 1 = 50% of amount recommended by NuMaSS; Level 2 = 100% of amounts recommended by NuMaSS; during 1999 season soil P was erroneously adjusted to level 2 in all treatments. Lime was only applied prior to planting in 1998 season. Fertilizer N was not applied to the selected cowpea treatments as originally planned.

b The only treatment where cowpea stover was left as residue in the field.

Table 29. Millet grain and stover N and P concentration in the 1998 season and subsequent cowpea grain and stover N and P concentration in the 1999 season as influenced by lime, N and P treatments in the "millet core experiment".

Millet - 1998 Season					Cowpea - 1999 Season				
Treat-ments	**Grain N conc.**	**Grain P conc.**	**Stover N conc.**	**Stover P conc.**	**Treat-ments**	**Grain N conc.**	**Grain P conc.**	**Stover N conc.**	**Stover P conc.**
	% of dry wt.					% of dry wt.			
N0P0L0a	1.37	0.28	0.40	0.06	N0P2L0	3.31	0.45	2.11	0.23
N0P0L2	1.33	0.32	0.33	0.04	N0P2L2	3.21	0.46	2.09	0.30
N0P1L2	1.37	0.29	0.31	0.05	N0P2L2	3.21	0.45	2.17	0.30
N0P2L2	1.30	0.30	0.40	0.09	N0P2L2	3.33	0.49	2.10	0.30
N0P2L0	1.27	0.30	0.37	0.05	N0P2L0	3.18	0.44	2.17	0.26
N0P2L1	1.36	0.31	0.36	0.07	N0P2L1	3.26	0.47	2.00	0.28
N0P1L1	1.33	0.29	0.39	0.09	N0P2L1	3.31	0.48	2.13	0.29
N0P2L2	1.33	0.31	0.31	0.06	N2P2L2	3.29	0.49	2.16	0.34
N0P2L2	1.27	0.48	0.52	0.08	N0P2L2b	3.34	0.50	2.20	0.37
N0P1L1	1.27	0.31	0.40	0.07	N1P2L1	3.20	0.46	2.07	0.28
LSD0.05	NS	NS	NS	NS		NS	NS	NS	NS
CV %	8.1	28.7	24.3	40.6		2.2	3.1	9.4	14.3

a Level 0 = no application of N, P or lime; Level 1 = 50% of amount recommended by NuMaSS; Level 2 = 100% of amounts recommended by NuMaSS; during 1999 season soil P was erroneously adjusted to level 2 in all treatments. Lime was only applied prior to planting in 1998 season.

b The only treatment inoculated with a mixture of two efficient Bradyrhizobium strains from Zimbabwe when planted to cowpea

3. *Philippines*

On-farm experiments to test diagnostic predictions and compare decision-aid predictions of nutrient requirements

(Thomas George, Teodula Corton, Josephina Lasquite and Russell Yost) the objectives of these on-farm trials were to test the nutrient decision-aids to determine whether they optimally diagnose and detect nutrient-responsive conditions and to document farmer diagnostic practices and crop management to improve diagnosis and prediction by NuMaSS. The on-farm testing continued on corn in 8 farms at the Ilagan project site and was expanded to Arakan valley in Mindanao on upland rice. Similar protocol as in Ilagan was implemented in Arakan on 17 cooperator farms. Plant analyses for 1999 trials were completed and available data from both 1999 and 2000 are reported here.

a. *Diagnosis and assessment of accuracy* - Site and soil properties of upland rice and corn farms in Ilagan and Arakan Valley in 1999 and 2000 are presented in Tables 30 through 33. For all crops and at both sites, NuMaSS diagnosed P and N deficiency in a majority of the farms and acidity as a constraint in only some farms. NuMaSS diagnoses and observed responses for the various crops and sites are summarized in Tables 34 through 37. Given that there were no replications for observed responses in each farm, a minimum 500 kg ha^{-1} increase in grain yield of upland rice and 1 t ha^{-1} increase in grain yield of corn in the NuMaSS treatment compared to the control treatment of zero input was recorded as a positive response. Note that while diagnoses were done for individual nutrient constraints, responses were measured for the combined application of the deficient nutrients. Kappa statistics were calculated to determine the agreement between the diagnoses and field observed responses. A Kappa value of 1 would indicate that diagnoses and field observed responses always matched. A Kappa value of 0 would indicate that there were an equal number of correct and incorrect diagnoses. The Kappa values for the various crops and sites varied from 0.85 to 1 indicating high accuracy in NuMaSS diagnoses, i.e., there was almost always an agreement between responses to combined application of N, P and lime when any one or all of them were diagnosed to be deficient.

b. *Prediction and testing of prediction* - Four treatments were implemented in 13 upland rice farms and 15 corn farms in Ilagan in 1999: 1) control (no NPK or lime), 2) farmer practice, 3) regional recommendation and 4) NuMass recommendation. A NuMaSS + K treatment was added for experiments in 8 corn farms in Ilagan in 2000 and in 17 upland rice farms in Arakan Valley in 2000. Since K applied in various amounts by farmers and is part of the regional recommendation but not considered by NuMaSS, NuMaSS + K treatment was included to test whether this element limited yield.

1. 1999 upland rice , Ilagan, Isabella - The farmer practice in the Ilagan 1999 upland rice trial varied widely in NPK use ranging in kg ha^{-1} from 0-134 for N, 0-18 for P and 0-35 for K; thus, some farmers were exceeding both regional and NuMaSS recommendations. Because of the observed wide variation in NPK rates across treatments, the NPK application levels were grouped in several classes and were assigned new NPK treatment designations (Table 38).

The new data set with the new NPK level designations were then subjected to cluster analysis. The data clustered only with respect to N and indicated that K was not a significant factor influencing yield. Nitrogen clusters were, N1 = 9-40 kg ha^{-1} and N2 = 60-138 kg ha^{-1}.

Table 30. Site and soil characteristics of farms, upland rice, Ilagan, Isabella, Philippines, 1999.

Site	Area	Slope	pH	Clay	Acidity	Al	Mehlich 1 P	K	Ca	Mg	ECEC
	ha	%		%	cmol kg^{-1}		mg kg^{-1}	------------- cmol kg^{-1} -------------			
1	0.50	8-16	4.06	35	1.87	1.74	0.60		1.93	2.10	5.90
3	0.75	8-16	3.90	45	2.66	2.58	1.01		1.28	1.26	5.22
9a	0.70	0-8	4.45	35	1.69	1.75	1.60	0.01	0.22	0.80	4.23
9b	0.70	0-8	4.45	35	1.69	1.75	1.40	0.04	0.22	0.80	2.75
12	0.25	0-8	3.81	40	1.45	1.37	1.46		1.50	1.10	3.05
13 a	0.75	0-8	4.95	35	1.49	0.76	*3.23**	0.02	1.46	1.38	4.35
13b	0.50	8-16	4.62	35	1.21	1.05	*3.23**	0.02	1.46	1.38	4.07
22c	0.75	8-16	4.61	35	1.59	1.72	1.60	0.01	2.93	1.38	5.91
31	0.50	8-16	3.81	40	1.45	1.37	1.46		1.56	1.00	4.01
32	0.50	0-8	3.72	42	2.19	2.06	2.32		1.07	1.07	4.33
53	0.40	0-8	4.05	37	1.75	1.69	1.40	0.02	0.42	0.80	2.99
57	0.50	0-8	3.89	41	1.60	1.59	1.36	0.02	0.39	0.60	2.61
58	0.30	0-8	4.43	35	1.37	1.37	*4.24**	0.02	1.46	1.38	4.23

*Olsen P

Table 31. Site and soil characteristics of farms, corn, Ilagan, Isabella, Philippines, 1999

Site	**Area**	**Slope**	**pH**	**Clay**	**Acidity**	**Al**	**Mehlich1 P**	**K**	**Ca**	**Mg**	**ECEC**
	ha	%		%	cmol kg^{-1}		mg kg^{-1}	------------- cmol kg^{-1} -------------			
5	0.50	8-16	3.70	39	2.65	2.42	1.60		0.66	0.48	3.79
9	0.75	0-8	3.7	39	2.65	2.42	1.60		0.66	0.48	3.79
16	0.50	0-8	4.12	41	1.79	1.79	1.63	1.05	0.23	0.06	3.13
17A	0.70	8-16	4.12	41	1.79	1.79	1.63	1.05	0.23	0.66	3.13
19	0.25	0-8	4.16	40	2.16	2.0	2.24	0.98	0.30	0.04	3.49
20A	0.50	0-8	4.76	35	0.40	0.35	*15.40**	1.02	1.52	1.01	3.95
22D	0.25	8-16	5.01	35	1.20	0.98	*35.03**	0.02	0.44	0.66	2.32
24B	0.25	8-16	5.01	35	1.18	1.12	*35.03**	0.22	0.23	0.04	1.67
27	0.50	8-16	4.89	35	0.67	0.41	*8.22**	0.20	0.30	0.02	1.19
28	0.50	8-16	4.16	42	2.10	2.0	2.24	0.98	0.30	0.04	3.49
29	0.50	8-16	4.12	41	1.79	1.79	1.63	1.05	0.23	0.06	3.13
30	1.0	8-16	4.93	35	.75	0.52	*8.20**	0.92	0.22	0.04	1.93
41	0.35	0-8	4.12	41	1.79	1.79	1.63	1.05	0.23	0.06	3.49
47	0.25	0-8	4.16	42	2.16	2.0	2.24	0.98	0.30	0.04	3.49
51D	1.0	0-8	4.89	35	0.67	0.52	*8.20**	0.22	1.56	1.10	4.24

*Olsen P

Table 32. Site and soil characteristics of farms, corn, Ilagan, Isabella, Philippines, 2000.

Site	**Area**	**Slope**	**pH**	**Clay**	**Acidity**	**Al**	**Mehlich1 P**	**K**	**Ca**	**Mg**	**ECEC**
	ha	%		%	cmol kg^{-1}		mg kg^{-1}	-------------- cmol kg^{-1} --------------			
3	0.50	8-16	5.25	35	0.26	0.14	1.09	0.18	4.04	3.09	17.57
4	0.20	0-8	5.17	35	0.15	0.8	1.08	0.52	5.54	17.94	24.15
6	0.50	8-16	4.61	35	0.54	0.41	1.34	0.10	4.83	13.34	18.8
8b	0.50	8-16	4.38	35	1.89	1.76	5.07	0.41	3.67	9.46	15.43
9	1.0	8-16	4.46	35	1.06	0.87	3.93	0.45	6.52	17.0	25.03
16	1.0	0-8	4.4	35	0.66	0.51	3.42	0.27	2.89	8.41	12.23
21b	0.75	8-16	4.27	35	5.11	4.94	2.12	0.30	7.45	23.81	36.67
17	0.50	0-8	4.52	35	1.58	1.48	2.55	0.14	1.02	4.80	7.55

Table 33. Site and soil characteristics of farms, upland rice, Arakan Valley, Philippines, 2000

Farm	**Slope**	**pH**	**Soil Texture**	**Acidity**	**Al**	**Mehlich1 P**	**K**	**Ca**	**Mg**	**ECEC**
	%			cmol kg^{-1}		mg kg^{-1}	-------------- cmol kg^{-1} --------------			
GI1	0-8	4.54	Loamy	0.39	0.11	1.29	0.41	5.79	18.01	24.60
GI2	8-16	4.98	Loamy	0.63	0.23	2.19	0.68	22.4	21.7	45.41
GI3	0-8	4.91	Loamy	0.035	0.12	1.5	0.56	22.31	24.56	47.79
GI5*										
GI7	0-8	5.24	Loamy	0.24	0.07	4.59	0.54	14.56	27.46	42.80
GI8	8-16	5.24	Loamy	0.24	0.07	4.59	0.54	14.56	27.46	42.80
DN9	8-16	5.70	Loamy	0.13	0.02	54.41[#]	1.13	19.66	26.55	47.48
DN11	0-8	4.64	Loamy	0.66	0.22	1.58	0.48	10.35	26.83	38.32
DN12	8-16	5.10	Loamy	0.68	0.21	3.84	0.50	22.59	21.72	45.49
TC14	8-16	5.43	Loamy	0.21	0.07	3.53	0.67	18.81	24.7	44.40
SS15	8-16	4.58	Loamy	0.37	0.13	8.76	0.10	27.77	7.43	35.43
GB16	8-16	4.65	Loamy	0.69	0.14	8.27	0.15	28.71	7.57	36.57
ES18	0-8	5.65	Loamy	0.06	0.02	20.2[#]	0.09	21.32	8.34	29.77
SD19	0-8	5.17	Loamy	0.12	0.04	12.84[#]	0.08	19.96	6.61	36.69
JD20	0-8	5.03	Loamy	0.11	0.03	5.36	0.12	18.90	4.90	23.95
RB21	0-8	4.94	Loamy	0.12	0.04	14.5[#]	0.11	20.83	7.03	27.56
JM22	0-8	4.64	Loamy	0.20	0.09	4.02	0.14	17.39	4.37	21.99

*Soil properties not available.

[#] Olsen P

Table 34. Assessing the accuracy of diagnosis, upland rice, Ilagan, Isabella, Philippines, 1999.

Diagnosis		Input	Farm												
			1	3	9a	9b	12	13a	13b	22c	31	32	53	57	58
Response	Pred.	N	+	+	+	+	+	+	+	+	+	+	+	+	+
		P	+	+	+	+	+	+	+	+	+	+	+	+	+
		Lime	-	+	-	-	+	+	+	-	+	+	-	+	+
	Obs. *	N+P+Lime	+#	+	+	+	+	-#	-	+	+	+	+	+	+
Kappa coefficient=0.85, n=13															

*Observed response is to any or all of the deficiencies diagnosed.
#An increase in grain yield of at least 500 kg ha^{-1} in the NuMaSS treatment compared to the zero input control is arbitrarily set as a positive response.

Table 35. Assessing the accuracy of diagnosis, corn, Ilagan, Isabella, Philippines, 1999.

Diagnosis		Input	Farm														
			5	9	16	17a	19	20a	22d	24b	27	28	29	30	41	47	51d
Response	Pred.	N	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		P	+	+	+	+	-	-	+	+	+	+	+	+	+	+	-
		Lime	-	-	+	+	-	-	+	+	-	+	-	+	+	+	-
	Obs. *	N+P+Lime	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Kappa coefficient=1, n=15																	

*Observed response is to any or all of the deficiencies diagnosed.
An increase in grain yield of at least 1 t ha^{-1} in the NuMaSS treatment compared to the zero input control is arbitrarily set as a positive response.

Table 36. Assessing the accuracy of diagnosis, corn, Ilagan, Isabella, Philippines, 2000.

Diagnosis		**Input**	**Farm**							
			3	**4**	**6**	**8b**	**9**	**16**	**21a**	**17**
Response	Pred.	N	+	+	+	+	+	+	+	+
		P	+	+	+	+	+	+	+	+
		Lime	-	-	-	-	-	-	-	-
	Obs. *	N+P+Lime	+	+	+	+	+	+	+	+
Kappa coefficient=1, n=8										

*Observed response is to any or all of the deficiencies diagnosed.
An increase in grain yield of at least 1 t ha^{-1} in the NuMaSS treatment compared to the zero input control is arbitrarily set as a positive response.

Table 37. Assessing the accuracy of diagnosis, upland rice, Arakan Valley, Philippines, 2000.

Farm	Diagnosis			Observed
	N	P	Lime	response*
GI1	+	+	-	+[#]
GI2	+	+	-	+
GI3	+	+	-	+
GI5	+	+	-	+
GI7	+	+	-	+
GI 8	+	+	-	+
DN9	+	-	-	+
DN11	+	+	-	+
DN12	+	+	-	+
TC14	+	+	-	+
SS15	+	+	-	+
GB16	+	+	-	+
ES 18	+	+	-	+
SD19	+	+	-	+
JD20	+	+	-	+
RB21	+	+	-	+
JM22	+	+	-	+
Kappa coefficient=1, n=17				

*Observed response is to any or all of the deficiencies diagnosed.
[#] An increase in grain yield of at least 500 kg ha^{-1} in the NuMaSS treatment compared to the zero input control is arbitrarily set as a positive response.

Table 38. Range of NPK amounts applied to upland rice in on farm trails at Ilagan, Isabella, 1999.

	Range of amounts applied, kg ha^{-1}			
Nutrient	None	Low	Medium	High
N	0	9-40	60-90	120-138
P	0	4-12	17-29	36
K	0	8-23	35	60-100

Analysis of variance using these two levels of N as treatments showed that yield is significantly different between these two clusters (p-value=0.0001) and about 78% of the variation in yield was accounted for by this grouping of N levels (Table 39). Uptake of N, P and K were also significantly different between these N clusters.

Given that K was not a significant factor in the 1999 Ilagan upland rice trial, an analysis of variance was performed with NuMass and NuMaSS+K data combined. NuMass and regional recommendation produced similar yields of 1.2 t ha^{-1}, which was significantly superior to farmer practice and control treatments (Table 40). Similar differences were observed for NPK uptake as well.

Table 39. Grain yield and nutrient uptake by upland rice, 1999, Ilagan, Isabella, Philippines. Data analyzed after separating into two N clusters.

N cluster	Grain Yield	N uptake	P uptake	K uptake
	---------- kg ha^{-1} ----------			
9 – 40	633b*	40b	4.8b	40.4b
60 – 138	1160a	86a	9.3a	66.8a

*Values in columns with the same letters are not significantly different at 5% level by LSD.

Table 40. Grain yield and nutrient uptake by upland rice subjected to various nutrient inputs, 1999, Ilagan, Isabella, Philippines.

	Inputs				Grain	Uptake		
Treatments	N	P	K	Lime	yield	N	P	K
	---------- kg ha^{-1} ----------				t/ha	------- kg ha^{-1} -------		
Control	0	0	0	0	0.59c*	37.6c	4.2d	38.2c
Farmer practice	0-134	0-18	0-35	0	0.93b	58.3b	6.8c	53.8b
Regional recommendation	90	9	18	0	1.21a	84.4a	8.8b	61.1ab
NuMaSS and NuMass + K	132	0-36	60-100	0-2000	1.21a	94.7a	10.5a	73.1a

*Values in columns with the same letters are not significantly different at 5% level by LSD.

2. <u>1999 corn, Ilagan, Isabella</u> - Analyses of variance indicated no significant differences in yield between regional and NuMaSS recommendations but only NuMaSS was superior to farmer practices (Table 41).

Table 41. Grain yield of corn in response to nutrient inputs, 1999 wet season, Ilagan, Isabella, Philippines.

	Inputs				Grain
Treatments	N	P	K	Lime	yield
	----- kg ha^{-1} -----			----- t ha^{-1} -----	
Control	0	0	0	0	1.25c
Farmer Practice	0-274	0-20	0-50	0	3.86b
Regional	134	18	35	0	4.82ab
NuMass	210	0-60	60	0-2	4.95a

*Values in columns with the same letters are not significantly different at 5% level by LSD.

3. <u>2000 corn, Ilagan, Isabela</u> - Analyses of variance indicated that there were no significant differences in yield among all treatments except the control receiving no inputs (Table 42).

Table 42. Grain yield of corn in response to nutrient inputs, 2000 wet season, Ilagan, Isabella, Philippines.

Treatments	Nutrients applied N	P	K	Grain yield
	---------- kg ha^{-1}	----------		t ha^{-1}
Control	0	0	0	1.36b
Farmer practice	90-120	12-25	12-23	2.52a
Regional	134	18	35	2.90a
NuMaSS + regional K	225	30-51	35	3.13a
NuMaSS + high K	225	30-51	80	3.10a

*Values in columns with the same letters are not significantly different at 5% level by LSD.

4. 2000 upland rice, Arakan Valley - Analysis of variance of grain yield data showed very large CV and low R^2 with no model significance. This was attributed to the fact that N applied under farmer practice varied widely overlapping with N levels in the regional and NuMaSS treatments. The CV was significantly reduced (20%) and R^2 improved to 91% when the farmer practice N levels were grouped into 16-45, 90 and 113-180 kg ha^{-1} classes and reanalyzed. The results indicated that grain yield under NuMaSS (with regional or high K), regional recommendation and farmer practice with 90 kg N ha^{-1} were similar but significantly higher than the control and farmer practice of low and high N (Table 43). It should be noted that farmer practice did not include any K application and except under low N, no P application as well.

Table 43. Grain yield of upland in response to nutrient inputs, 2000 wet season, Arakan Valley, Philippines.

Treatment	Nutrients applied N	P	K	Grain yield
	------ kg ha^{-1}	------		t ha^{-1}
Control	0	0	0	0.99c
Farmer practice				
High N	113-180	0	0	1.34c
Medium N	90	0	0	1.77b
Low N	16-45	0-22	0	1.20c
Regional	90	26	25	2.07ab
NuMaSS + regional K	132	0-12	25	2.20a
NuMaSS + high K	132	0-12	67	2.05ab

*Values in columns with the same letters are not significantly different at 5% level by LSD.

Discussion - The on-farm trials collectively indicated that there is a high degree of accuracy in diagnosing constraints of N, P and acidity by NuMaSS. However, the yields achieved for both upland rice and corn were substantially lower than the target yields for which NuMaSS diagnoses and recommendations were made. In general, NuMaSS recommendations resulted in similar yields as the regional recommendation both at the more acid upland site in Ilagan, Isabella and at the less acid site in Arakan Valley for both upland rice and corn crops. Thus, NuMaSS performed as well as the regional recommendation. But it should be noted that K which is routinely included in the regional recommendation is not currently addressed in NuMaSS. It should be also noted that there were instances where farmer practice yielded the same as regional and NuMaSS recommendations and often with no P and K applied and never any lime applied. A cluster analyses on 1999 upland rice yield in Ilagan indicated that there was a yield response to N but not to P, K or lime. The results overall confirm N but not P, K or acidity as a limitation to yield of upland rice and corn. It cannot be concluded, however that P, K or acidity was not limiting yields since the response to NuMaSS recommendation was observed collectively for N, P and lime. It is likely that the soil P and K supplies were sufficient to support the relatively low yields achieved in the trials. Economic assessment and long term performance of NuMaSS could be evaluated only by accounting for residual effects of P and lime inputs. Although, cooperators were approached about repeating trials on the same plots, only a few farmers repeated their crops in the succeeding year for various reasons including lack of timely rainfall and fallowing the land.

The conclusions that can be drawn are:

- NuMaSS performs as well as the regional recommendation.
- Although NuMaSS target yields were reasonable for the regions, in none of the experiments were such yields produced.
- The treatment combinations did not permit testing whether there were responses to individual nutrient constraints for which NuMaSS diagnoses and recommendations were separately made.

The following recommendations are made for improvement of NuMaSS and the on-farm evaluation of it:

- Achieving target yields may require considerations of other limiting factors such as genotype and time of planting in relation to drought events.
- Currently, P and lime diagnoses and recommendations are based on soil critical levels and are not linked to target yields. Perhaps there is a need to link lime and P diagnoses and recommendations in NuMaSS to target yields.
- Many farmers stiIl use low yielding traditional varieties, however, NuMaSS would still make input recommendations which are suitable and economical only at high yield levels.
- In order to test the success of diagnoses of individual inputs, additional NuMaSS minus-one treatments should be included in on-farm evaluation of NuMaSS. Thus, NuMaSS - N, NuMaSS - P and NuMaSS - lime treatments are recommended. A significant response to NuMaSS treatment compared to NuMaSS – N treatment for example would indicate that the N was indeed deficient.
- It is recommended that two or more replication of treatments are implemented on each farm. This would allow testing of responses on a per farm basis in addition to across all farms.
- Potassium should be included in NuMaSS because it is part of routine regional and national recommendations.
- Land slope should be included as a recommendation criterion in NuMaSS. Recommendations of for large amounts of inputs should not be made for erosion prone lands.

Estimating biologically-fixed N (BNF) inputs in core experiments at the Philippine site (Thomas George, Teodula Corton, Josephina Lasquite, Russell Yost) Estimates of N derived from biological nitrogen fixation (BNF) in response to N, P and lime inputs in the core experiment at Ilagan, Isabella, Philippines were made. Peanut, soybean and mungbean were grown in the experiments in three different seasons. The BNF amount was determined by using the total N uptake of a non-nodulating soybean isoline that was included as one of the treatments. The results are summarized in Tables 44 through 52 and in Figures 7 through 9. The major effect on BNF was from P application; soybean BNF and total N increased substantially while total N and BNF of peanut and mungbean was influenced less so. Nitrogen and lime had no significant effects on total N of all legumes but N decreased the amount of BNF. The total N uptake was strongly related to P uptake in all legumes and appeared to have the same slope when total N and P uptake of all three legumes were plotted together. Accordingly, for every unit uptake of P, there was a corresponding uptake of approximately 9 kg N ha^{-1}. It appears that P fertilzation is the key to realizing increased inputs of BNF in acid uplands such as in Ilagan, Isabella, Philippines. Next step will be to further quantify the BNF benefits so that appropriate predictions of BNF inputs and management options to maximize such benefits could be incorporated into NuMaSS.

Table 44. Effect of N on biologically fixed N (BNF) by peanut, Ilagan, Isabela, Philippines, 1999.

Inputs					
N	**Lime**	**P**	**Total N**	**Soil N***	**BNF***
kg ha^{-1}	t ha^{-1}	-------------------- kg ha^{-1} --------------------			
0	4.18	60	174.5a	44.5	131.0
30	4.18	60	168.9a	59.5	109.4
120	8.37	60	175.6a	104.5	71.0

*The total N uptake by non-nodulating soybean is used as an estimate for N derived from soil by the fixing legume. A 50% recovery was assumed for N fertilizer applied. N from BNF = Total N – N from soil.

Table 45. Effect of P application on biologically fixed N by peanut, Ilagan, Isabela, Philippines, 1999.

Inputs			Mehlich 1				
N	**Lime**	**P**	**P[a]**	**Total N**	**Soil N***	**BNF**	**P uptake**
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	mg kg^{-1}	-------------------- kg ha^{-1} --------------------			
30	4.18	0	2.89c	161.9a	59.5	102.3	10.5b
30	4.18	30	6.48c	170.4a	59.5	110.8	14.6ba
30	4.18	60	14.49b	168.9a	59.5	109.4	17.0a
30	4.18	120	22.33a	177.8a	59.5	118.3	18.0a

[a] After harvest.

*The total N uptake by non-nodulating soybean is used as an estimate for N derived from soil by the fixing legume. A 50% recovery was assumed for N fertilizer applied. N from BNF = Total N – N from soil.

Table 46. Effect of lime application on biologically fixed N by peanut, Ilagan, Isabela, Philippines, 1999.

Inputs					
N	Lime	P	Total N	Soil N*	BNF*
kg ha^{-1}	t ha^{-1}	-----------------	kg ha^{-1}	-----------------	
0	4.18	120	187.0a	44.5	142.5
0	8.37	120	185.9a	44.5	141.3

*The total N uptake by non-nodulating soybean is used as an estimate for N derived from soil by the fixing legume. A 50% recovery was assumed for N fertilizer applied. N from BNF = Total N – N from soil.

Table 47. Effect of N on biologically fixed N (BNF) by soybean, Ilagan, Isabela, Philippines, 2000.

Inputs					
N	Lime	P	Total N	Soil N*	BNF*
kg ha^{-1}	t ha^{-1}	-----------------	kg ha^{-1}	-----------------	
0	4.18r*	50f*+60r	103.5a	57.9	45.6
30	4.18r	50f+60r	112.6a	62.9	39.7
135	8.37r	50f+60r	126.0a	125.4	0.7

f=freshly applied, r=residual from 1999 Peanut application

*The total N uptake by non-nodulating soybean is used as an estimate for N derived from soil by the fixing legume. A 50% recovery was assumed for N fertilizer applied. N from BNF = Total N – N from soil.

Table 48. Effect of P application on biologically fixed N by soybean, Ilagan, Isabela, Philippines, 2000.

Inputs			Mehlich 1 P[a]					
N	Lime	P[+]	Before	After	Total N	Soil N	BNF*	P uptake
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	--- mg kg^{-1} ---		-------------	kg ha^{-1}	-------------	
30	4.18r	0	3.99	1.06 b	45.8c	45.8	0	2.3c
30	4.18r	25f+30r	4.65	4.28 b	83.0b	57.9	10.1	7.8b
30	4.18r	50f+60r	8.20	6.25 b	112.6ba	57.9	39.7	11.4a
30	4.18r	100f+120r	12.40	13.02 a	130.9a	57.9	58.0	13.6a

[+]r=residual, f=freshly applied

[a] samples taken before and after harvest

*The total N uptake by non-nodulating soybean is used as an estimate for N derived from soil by the fixing legume. A 50% recovery was assumed for N fertilizer applied. N from BNF = Total N – N from soil.

Table 49. Effect of lime application on biologically fixed N by soybean, Ilagan, Isabela, Philippines, 1999.

Inputs					
N	Lime	P	Total N	Soil N*	BNF*
kg ha^{-1}	t ha^{-1}	--------------- kg ha^{-1} --------------			
0	4.18r[1]	100f+120r	133.2a	57.9	75.3
0	8.37r	100f+120r	128.4a	57.9	70.6

* The total N uptake by non-nodulating soybean is used as an estimate for N derived from soil by the fixing legume. A 50% recovery was assumed for N fertilizer applied. N from BNF = Total N – N from soil.

[1]r=residual from 1999 Peanut application

Table 50. Effect of N on biologically fixed N (BNF) by mungbean, Ilagan, Isabela, Philippines, 2000.

Inputs					
N	Lime	P	Total N	Soil N*	BNF*
kg ha^{-1}	t ha^{-1}	-------------------- kg ha^{-1} --------------------			
0	0.5f[1] + 4.18r2[1]	60f+50r1[1]+60r2	46.9a	59	0
30	0.5f + 4.18r2	60f+50r1+60r2	60.0a	59	0
210	0.5f + 8.37r2	90f+50r1+60r2	52.9a	>52.9	0

* The total N uptake by non-nodulating soybean is used as an estimate for N derived from soil by the fixing legume. A 50% recovery was assumed for N fertilizer applied. N from BNF = Total N – N from soil.

[1]f=freshly applied, r1=residual from 2000 soybean, r2=residual from 1999 peanut

Table 51. Effect of P application on biologically fixed N by mungbean, Ilagan, Isabela, Philippines, 2000.

Inputs			Mehlich 1-P		Total			P
N	Lime	P	Before	After	N	Soil N*	BNF*	uptake
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	mg kg^{-1}		------------- kg ha^{-1} -------------			
30	0.5f+ 4.18r2	0	1.06 b	2.30	19.5b	>19.5	0	1.5b
30	0.5f +4.18r2	30f+25r1+30r2	4.28 b	5.80	49.3a	>49.3	0	5.2a
30	0.5f +4.18r2	60f+50r1+60r2	6.25 b	9.17	60.0a	59	1	6.8a
30	0.5f +4.18r2	90f+100r1+120r2	13.02 a	16.11	55.4a	>55.4	0	6.2a

* The total N uptake by non-nodulating soybean is used as an estimate for N derived from soil by the fixing legume. A 50% recovery was assumed for N fertilizer applied. N from BNF = Total N – N from soil.

[1]f=freshly applied, r1=residual from 2000 soybean, r2=residual from 1999 peanut

Table 52. Effect of lime application on biologically fixed N by mungbean, Ilagan, Isabela, Philippines, 1999

Inputs					
N	Lime	P	Total N	Soil N*	BNF*
kg ha^{-1}	t ha^{-1}		kg ha^{-1}		
0	0.5f +4.18r2	100r1+120r2	47.5a	47.5	0
0	4.0f +8.37r2	100r1+120r2	55.9a	52.9	0

* The total N uptake by non-nodulating soybean is used as an estimate for N derived from soil by the fixing legume.   A 50% recovery was assumed for N fertilizer applied. N from BNF = Total N – N from soil.
[1]f=freshly applied, r1=residual from 2000 soybean, r2=residual from 1999 peanut

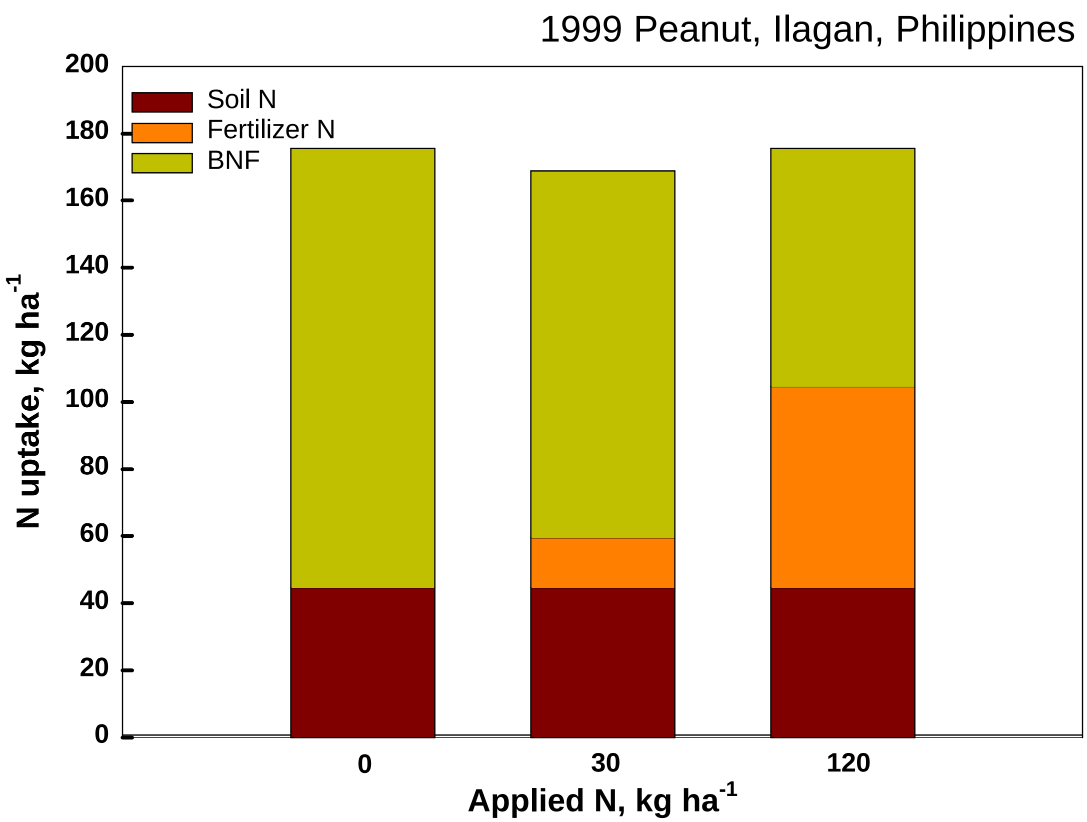

Figure 7. Effect of applied N on soil N , BNF and total N uptake by peanut, 1999, Ilagan, Philippines.

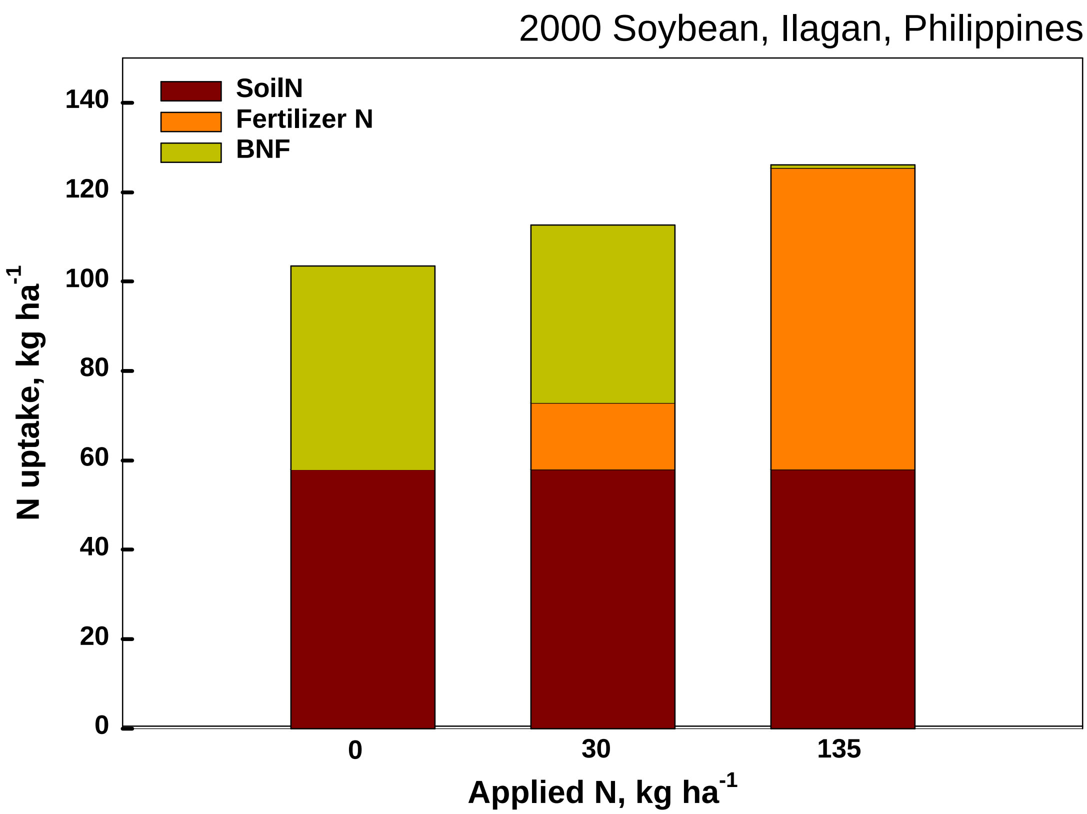

Figure 8. Effect on applied N on soil N, BNF and total N uptake by soybean, 2000, Ilagan, Philippines

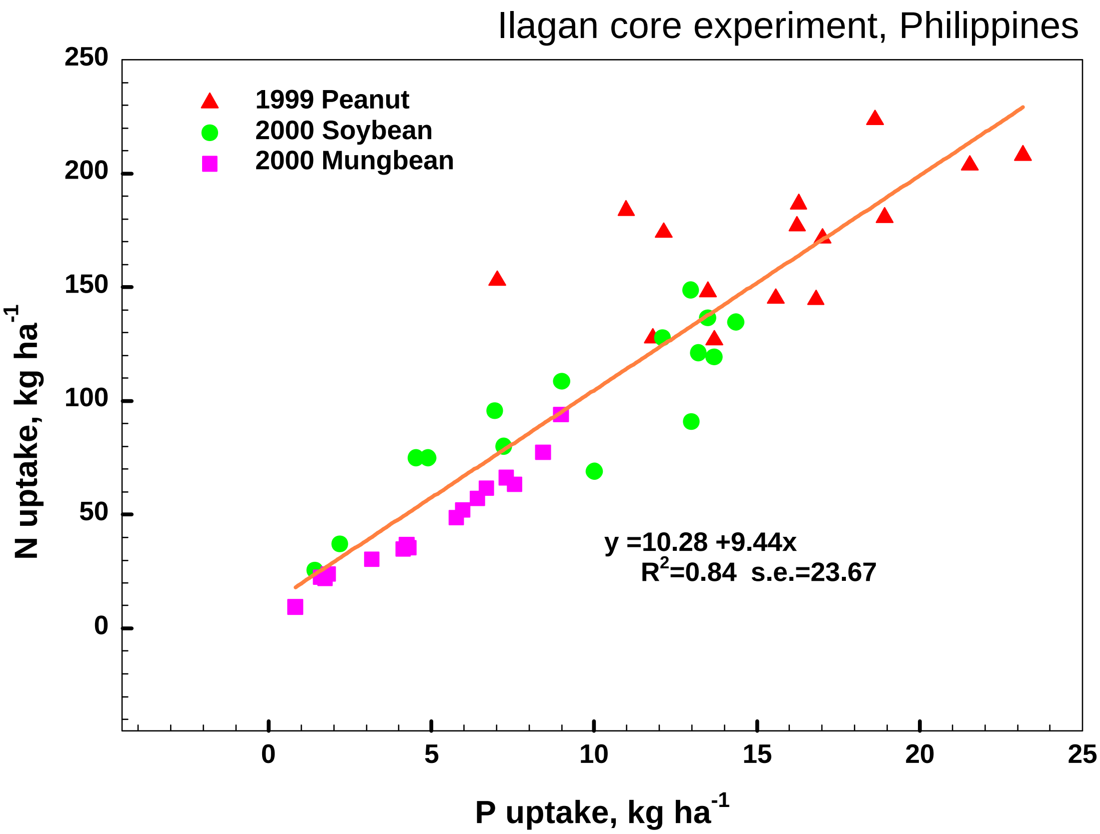

Figure 9. P uptake vs. N uptake, 1999 peanut, 2000 soybean and 2000 mungbean, Ilagan core experiment, Philippines

<u>Investigation of Mn toxicity problem in the Core Experiment Site in Brangay San Antonio, Isabela, Philippines</u>

(Jocelyn Bajita, Josefina Lasquite, Russell Yost with collaboration of Quirino Asuncion)

This investigation had the following objectives: 1. collect available information on the extent of Mn toxicity problem in the acid uplands of the Philippines and the methods used to diagnose the problem; 2. observe the extent to which Mn toxicity is expressed in the growing crop and gain insight on how Mn toxicity can complicate responses to lime, P and green manure application in an acid upland soil; and 3. conduct field, greenhouse and lab experiments to assess the realative contribution of various management practices (variety, liming, green manure application) on manganese toxicity in an acid upland soil.

Literature search at the IRRI library revealed no past nor recent investigations on Mn toxicity in the acid uplands. There were occasional papers and thesis written on Mn availability and excess in paddy rice fields but not in the acid uplands. To date there is no existing estimate of the potential risk of acid soils for Mn toxicity from the Philippine Bureau of Soils and Water Management or from other institutions like University of the Philippines Los Banos that conducts research on acid soils. Dr. Rodrigo Badayos, a professor and geologist of the university and his staff constructed a map of ultrabasic rock derived soils that may be useful in locating high Mn soils in the Philippines.

Local farmers in San Antonio are well aware that many soils in their *barangay* and nearby areas have manganese nodules they call "*bagiing*". These "*bagiings*" they reported, can cause problems in their crop when episodes of heavy rains come and their crop is still young. The corn and rice crop in the area appears to be normal and do not show symptoms of Mn toxicity. The travel coincided with the summer crop June-September 2000 when majority of the farmers are growing corn. Some flat areas, small valleys and footslopes are planted to rice, while some more steep areas are planted to vegetables. The summer months, according to the experiment station personnel used to have episodes of heavy rains starting in August. There was less rain in 2000, about 7 mm maximum and about two short rainshowers once in two weeks during the conduct of the field experiment. Heavier rains were experienced only when typhoons and tropical depressions develop.

Officials of Ilagan Experiment Station and PhilRice were contacted initially to discuss the pre-planned experiments and get their suggestions, comments and ideas regarding the problem addressed by the planned study. They expressed their support in terms of the use of experiment station facilities. The field experiment was established at Centro San Antonio, Ilagan Isabela, Philippines on June 28, 2000, after 4 weeks of preparation of the field site and materials. Seeds of soybean UPL Sy2 and UPL Sy6, rated as acid susceptible and acid tolerant, respectively, were obtained from IES and Institute of Plant Breeding. The experimental site identified by Mr. Asuncion is owned by the *barangay* school and is located about 400 meters northeast of the Core Experiment of the SM-CRSP. The pot experiment was established on June 28, 2000 at the screenhouse facility of the IES. The laboratory experiment was conducted at the Soils Laboratory of PhilRice. The establishment of both field and pot experiment was facilitated by Ms. Lasquite and Mr. Asuncion with the participation of other IES staff and local field workers in San Antonio. The same persons helped during sampling of soil and plants from the experiments. Soils and plant samples were brought to PhilRice immediately after sampling for processing and analysis, and for measurements such as leaf area and biomass weight. Plant observations on Mn toxicity symptoms were made on-site and digital pictures were taken to document the symptoms.

The soil used in the experiments is a *fine, isohyperthermic Typic Kandiudalfs*, very acid (pH 4.5), high in Al (47% in the exchange complex) and low in exchangeable bases (2.5 cmol kg-1). I tested the effects of lime, green manure and variety on toxicity responses of soybean to Mn toxicity. Water availability treatments were also tested in the greenhouse experiment.

The field-grown soybean showed severe of Mn toxicity characterized by the following symptoms:

appearance of black speckles, black spots and lesions in older leaves, irregular yellowing of interveinal tissues of young and old leaves, and crinkling of young leaves.

These symptoms started to develop during the primary leaf stage and were fully expressed at two weeks after planting. A rating scheme was devised: 1 for plants having no symptom and 5 for plants showing all the symptoms described above. Symptoms were most severe in plots without lime. Soybean variety *UPL SY2* appeared to be more tolerant of soil acidity compared to *UPL SY6* as shown by less severe symptoms and higher leaf concentrations of Ca. Plants with severe leaf symptoms were also severely stunted. The plants somewhat recovered, exhibiting less symptom during the next two weeks of growth. Six weeks after planting, the symptoms became more severely expressed particularly in unlimed plots where no green manure was added. Folding of the leaves of *UPL SY2* was observed at this stage. Liming and green manure application appeared to help the plants grow bigger and faster as shown by higher biomass growth rates, leaf expansion rates, and specific leaf weights (Table 53). This effect was very pronounced both in limed and unlimed plots. Liming reduced leaf Mn concentration from about 1,300 mg kg^{-1} to 460 mg kg^{-1}. Without lime application, green manure application significantly reduced leaf Mn. Seed yield was significantly increased by liming and green manure application, and was significantly less in UPL SY6 across liming and green manure treatments (Table 53).

The soybean plants in the greenhouse did not show any serious symptoms of Mn toxicity except for some treatments where the old leaves showed few black spots. We think that this happened for two reasons: the soil was incubated under field capacity for two weeks before planting soybean and that greenhouse conditions (temperature and water?) favored a faster growth rate for the plants during the first two weeks. Greenhouse plants tended to be bigger and healthier during the first two weeks, as compared with field plants. Field and greenhouse plants also differed in stature, the field plants were shorter but with thicker leaves and stems while the greenhouse plants were taller, with thinner leaves and stems. Eventually, greenhouse plants exhibited viny growth which according to Ms Rosie, soybean expert of IES, normally happens when soybean is grown under partly shaded condition and is constantly supplied with water. Liming and green manure application significantly increased leaf and biomass growth rates and leaf area at 6 weeks after planting (Table 54). Applying green manure increased leaf Mn from 283 mg kg^{-1} to 499 mg kg^{-1} without lime application. With lime, leaf Mn averaged at 227 mg kg^{-1} and did not differ significantly with lime or green manure application (Table 54).

Table 53. Toxicity ratings, biomass production and leaf area of two field-grown soybean varieties grown in acid soil of the Barangay San Antonio, Ilagan, Isabela, Philippines. June-October 2000.

Lime	Green Manure	Variety	Toxicity Ratings[a] Wk 2	Wk 4	Wk 6	Biomass Wk 4 Leaf	Biomass Wk 4 Plant	Biomass Wk 6 Leaf	Biomass Wk 6 Plant	Leaf Area Wk 4	Leaf Area Wk 6
$t\ ha^{-1}$						$g\ m^{-2}$				$cm^2\ m^{-2}$	
0	0	UPL Sy2	3.50	2.75	3.38	4.35	7.04	7.34	13.15	199.3	1598.5
0	0	UPL Sy6	4.00	3.38	4.00	4.40	7.33	6.79	12.40	296.2	1925.5
0	7	UPL Sy2	2.13	2.25	2.13	5.01	8.64	13.10	25.28	277.1	3113.6
0	7	UPL Sy6	3.03	2.75	3.13	4.06	7.17	9.24	16.28	160.9	2060.3
5	0	UPL Sy2	1.13	1.00	1.13	5.37	9.44	14.26	27.06	585.0	3746.2
5	0	UPL Sy6	2.50	2.63	2.63	6.55	11.38	14.85	27.86	285.9	3126.0
5	7	UPL Sy2	1.00	1.00	1.00	6.01	10.29	21.33	38.71	572.5	2810.6
5	7	UPL Sy6	2.63	2.38	2.63	5.16	9.02	11.12	24.86	978.5	2633.7
$LSD_{0.05}$			0.34	0.36	0.34	0.58	1.00	3.98	5.34	359.3	622.3

[a] 1(healthy)-5(severe symptoms)

Table 54. Leaf Mn, growth rates and yield of two field-grown soybean varieties grown to acid soil in Barangay San Antonio, Ilagan, Isabela, Philippines. June-October 2000.

Lime	Green Manure	Variety	Growth rate[a] Leaf	Growth rate[a] Plant	Leaf Mn Wk 4	Leaf Mn Wk 6	Seed yield
$t\ ha^{-1}$			$mg\ d^{-1}$		$mg\ kg^{-1}$		$kg\ ha^{-1}$
0	0	UPL Sy2	38.04	68.3	2125	1577	690
0	0	UPL Sy6	30.67	68.93	1733	1461	569
0	7	UPL Sy2	82.24	155.42	1506	1090	1499
0	7	UPL Sy6	56.49	97.60	1496	988	1148
5	0	UPL Sy2	80.09	153.46	445	367	1848
5	0	UPL Sy6	68.68	127.98	596	470	1663
5	7	UPL Sy2	114.73	205.96	571	483	1945
5	7	UPL Sy6	80.76	146.58	511	519	1660
$LSD_{0.05}$			11.43	20.18	218	321	181.41

[a] (within 6-wk period).

Table 55. Biomass production, growth rates, leaf area and leaf Mn of two greenhouse-grown soybean varieties grown to acid soil in Barangay San Antonio, Ilagan, Isabela, Philippines. June-October 2000.

				Biomass								
	Green			**Wk 4**		**Wk 6**		**Growth Rate[a]**		**Leaf Area**		**Leaf**
Lime	**Manure**	**Variety**	**Water**	**Leaf**	**Plant**	**Leaf**	**Plant**	**Leaf**	**Plant**	**Wk 4**	**Wk 6**	**Mn**
$t\ ha^{-1}$				$g\ plant^{-1}$				$mg\ d^{-1}$		$cm^2\ plant^{-1}$		$mg\ kg^{-1}$
0	0	UPL Sy2	Field Cap	0.400	0.802	1.296	2.824	41.1	91.1	208.2	572.7	273
0	0	UPL Sy2	Wet	0.442	0.849	1.776	3.731	58.5	124.5	280.3	712.2	
0	0	UPL Sy6	Field Cap	0.412	0.822	1.214	2.887	39.9	74.9	289.9	426.8	293
0	0	UPL Sy6	Wet	0.302	0.742	1.415	3.261	45.7	107.3	220.8	710.4	
0	7	UPL Sy2	Field Cap	0.521	1.070	2.481	5.017	82.5	167.5	390.3	985.1	586
0	7	UPL Sy2	Wet	0.453	0.948	2.454	5.241	83.4	179.4	276.4	1028.0	
0	7	UPL Sy6	Field Cap	0.286	0.680	1.928	4.488	65.5	15.0	200.1	774.9	412
0	7	UPL Sy6	Wet	0.285	0.609	2.018	4.503	67.8	153.1	198.7	1060.2	
5	0	UPL Sy2	Field Cap	0.352	0.729	1.189	2.374	36.8	74.4	226.2	397.1	209
5	0	UPL Sy2	Wet	0.399	0.807	1.287	2.523	41.6	81.6	256.5	461.5	
5	0	UPL Sy6	Field Cap	0.186	0.425	0.945	1.191	29.0	69.2	130.9	402.4	227
5	0	UPL Sy6	Wet	0.299	0.772	0.918	2.148	28.2	53.5	213.0	437.8	
5	7	UPL Sy2	Field Cap	0.471	0.918	1.760	3.715	58.4	123.7	283.3	671.5	225
5	7	UPL Sy2	Wet	0.412	0.845	1.001	2.210	29.7	68.5	276.1	437.9	
5	7	UPL Sy6	Field Cap	0.352	0.773	1.215	2.844	40.1	95.2	254.9	491.8	247
5	7	UPL Sy6	Wet	0.273	0.649	1.443	3.281	47.3	108.7	199.9	509	
$LSD_{0.05}$				0.057	0.103	0.264	0.619	8.8	20.6	34.3	106.3	90

Field Cap – field capacity

[a] (within 6-wk period)

Core experiment top test individual module predictions of nutrient requirements and to develop supporting data to estimate interactions among N, P and lime rates

(Teodula Corton, Miguel Aragon, Russell Yost, Thomas George, Josefina Lasquite with collaboration from Santiago R. Obien, Segunda Santiago, Danilo B. Tumamao, Quirino Asuncion and Thomas George) objectives of this investigation are to: 1) conduct factorial experiments that will support Level 0 (comparing yield predictions) testing of the ADSS, PDSS and NDSS or equivalent N recommendations methodology for alternative upland cropping systems; 2) collect data for Level 1 (both yield prediction and parameter testing) for a selected cropping system for PDSS, ADSS and NDSS; and 3) develop management alternatives (crop and amendment combinations) that might be used in subsequent outreach testing locations throughout the non-irrigated rice-based systems in the Philippines.

Field experiments were conducted for cereal (rice and corn) and legume crops (peanut, soybean and mungbean) during the 1998-2000 cropping seasons in Ilagan, Isabela, Philippines. Crop responses to lime, N and P are summarized in Tables 56-67 (rice, corn) and Tables 69-83 (peanut, soybean, mungbean) . Soil analysis after harvest of the 2000 corn crop showed a significant increase in soil pH and a decrease in exchangeable aluminum where lime was applied (Table 68). Phosphorus uptake and N uptake were strongly related in both upland rice and corn (Fig. 14).

The 1998 rice crop did not respond to lime, N and P application. Grain yield across treatments was at least 2 t ha^{-1}, which is far below the target of 3.5 t ha^{-1}. While upland rice in 1998 did not respond to any of the N, P or lime inputs, it did respond to P in 1999; grain yield, N and P uptake significantly increased with P application. The relationship between Mehlich 1 P at crop harvest and grain yield produced a scatter plot in 1998 (Fig. 10) while in 1999 (Fig. 12) the data fit a linear-response-plateau model. The critical Mehlich 1 P level of 6.2 mg kg^{-1} was identified in 1999.

There was no yield response to N application in the 1999 corn crop while a significant response was obtained in 2000. Significant increase in grain yield was obtained at the highest lime rate in both years. There was a response to P in both years, but only at the highest P rate of 90 kg P ha^{-1} which received also the highest rate of N of 300 kg ha^{-1}. Analysis of covariance indicated that there were no interaction between P treatment levels and N uptake, and therefore, the differences in the N rate between the P levels was considered not to significantly influence the yield response to the high P rate. The relation between Mehlich 1 P at harvest and corn yield shown in Fig 11 and 13 indicate a critical P level of 17.5 mg kg^{-1} in 1999 and 9.3 mg kg^{-1} in 2000.

The peanut crop did not respond to the small initial N application nor to lime application. However, further analysis showed that lime contributed to yield when green manure was also applied (Table 73). Phosphorus response was significant at 30 kg ha^{-1} rate, with no further response with additional P applied. Similarly, soybean did not respond to N and lime application. Lime appeared to increase grain yield, N and P uptake only when green manure is present (Table 78). Grain yield, N and P uptake increased significantly with the application of P up to 50 kg ha^{-1} (with P residual from previous crops). Mungbean responded to 30 kg N ha^{-1} application. Lime response was not observed, even when applied with green manure (Table 83). A strong P response was obtained up to 60 kg ha^{-1} P plus residuals. Critical P levels identified for the legumes appeared to be very low at about 5.8 mg kg^{-1} for peanut and 4.8 mg kg^{-1} for soybean (Fig 15 and 16).

Table 56. Nitrogen response, 1998 Rice, Ilagan

Inputs					
N	**Lime**	**P**	**N uptake**	**P uptake**	**Grain yield**
kg ha^{-1}	t ha^{-1}		kg ha^{-1}		
0	6	30	77.3a	10.1a	1917a
40	6	30	79.5a	10.1a	1952a
80	6	30	81.4a	8.3a	2004a
120	6	30	96.6a	9.9a	1711a

Table 57. P response, 1998 Rice, Ilagan

Inputs						
N	**Lime**	**P**	**Mehlich 1-P**	**N uptake**	**P uptake**	**Grain Yield**
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	ug g^{-1}	---------- kg ha^{-1} ----------		
80	6	0	10.6a	84.2a	7.6a	1636a
80	6	15	19.5a	81.4a	7.2a	1692a
80	6	30	14.4a	77.6a	8.3a	2004a
120*	6	60	20.5a	98.0a	9.4a	1772a

*The higher N rate treatment included in the analyses since the ANOCOVA analysis for interaction between N uptake (as a proxy to N applied) and P treatment levels was not significant.

Table 58. Lime response, 1998 Rice, Ilagan.

Inputs					
N	**Lime**	**P**	**N uptake**	**P uptake**	**Grain Yield**
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	---------- kg ha^{-1} ----------		
80	0	30	69.4a	7.2a	1680a
80	3	30	81.4a	8.3a	1643a
80	6	30	70.8a	7.4a	2004a

Table 59. N response, 1999 Corn, Ilagan

Inputs					
N	**Lime**	**P**	**N uptake**	**P uptake**	**Grain Yield**
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	---------- kg ha^{-1} ----------		
0	6r*	45	65.9b	2.9a	4650a
100	6r	45	76.9ab	3.4a	5084a
200	6r	45	70. 7ab	3.4a	4623a
300	6r	45	82.9a	3.2a	5377a

*r=residual from 1998 Rice

Table 60. P response, 1999 Corn, Ilagan

Inputs			Mehlich 1 P			
N	Lime	P	after harvest	N uptake	P uptake	Grain yield
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	mg kg^{-1}	---------- kg ha^{-1} ----------		
200	6r[1]	0	2.8c	62.1b	2.5b	3971b
200	6r	22.5	3.9 cb	78.9ab	3.0b	4791b
200	6r	45	8.4b	70.7b	3.4b	4622b
300*	6r	90	17.3a	98.6a	4.8a	6208a

[1]r=residual from 1998 Rice

* The higher N rate treatment included in the analyses since the ANOCOVA analysis for interaction between N uptake (as a proxy to N applied) and P treatment levels was not significant

Table 61. Lime response, 1999 Corn, Ilagan

Inputs					
N	**Lime**	**P**	**N uptake**	**P uptake**	**Grain yield**
kg ha^{-1}	t ha^{-1}	--------------- kg ha^{-1} ---------------			
200	0	30	66.3b	2.6b	4275b
200	3r*	30	87.3a	3.5a	4623b
200	6r	30	70.7b	3.4a	5688a

*r=residual from 1998 Rice

Table 62. N response, 1999 Rice, Ilagan.

Inputs					
N	**Lime**	**P**	**N uptake**	**P uptake**	**Grain Yield**
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	---------- kg ha^{-1} -----------		
0	6r*	45	32.0c	6.1b	1011c
50	6r	45	46.6b	8.0ab	1511bc
100	6r	45	68.6a	8.3ab	1691ba
150	6r	45	77.9a	10.3a	2079a

*r=residual from 1998 Rice

Table 63. P response, 1999 Rice, Ilagan.

Inputs			Mehlich 1 P			
N	**Lime**	**P**	**after harvest**	**N uptake**	**P uptake**	**Grain Yield**
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	mg kg^{-1}		kg ha^{-1}	
200	6r[1]	0	2.3c	50.7b	4.8b	1136b
200	6r	22.5	5.7cb	63.2b	8.4a	1567ba
200	6r	45	9.2ba	68.6a	8.3a	1691a
300*	6r	90	12.4a	82.4a	10.5a	2017a

[1]r=residual from 1998 Rice

* The higher N rate treatment included in the analyses since the ANOCOVA analysis for interaction between N uptake (as a proxy to N applied) and P treatment levels was not significant.

Table 64. Lime response, 1999 Rice, Ilagan.

Inputs					
N	**Lime**	**P**	**N uptake**	**P uptake**	**Grain Yield**
kg ha^{-1}	t ha^{-1}	---------------	kg ha^{-1}	---------------	
200	0	30	71.4a	7.6a	1730a
200	3r*	30	60.9a	7.8a	1441a
200	6r	30	68.6a	8.3a	1691a

*r=residual from 1998 Rice

Table 65. N response, 2000 Corn, Ilagan.

Inputs					
N	**Lime**	**P**	**N uptake**	**P uptake**	**Grain Yield**
kg ha^{-1}	t ha^{-1}			kg ha^{-1}	
0	6r*	60	82.7c	14.5a	5283c
100	6r	60	111.8b	15.7a	5802b
200	6r	60	132.8a	19.2a	5818b
300	6r	60	128.78ab	18.8a	6161a

*r=residual from 1998 Rice

Table 66. P response, 2000 Corn, Ilagan

Inputs			Mehlich 1 P			
N	Lime	P	after harvest	N uptake	P uptake	Grain Yield
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	ug g^{-1}		kg ha^{-1}	
200	6r[1]	0	2.2b	45.6c	4.7c	2044d
200	6r	30	10.4b	102.2b	12.6b	4822c
200	6r	60	13.2b	132.8a	19.2a	5818b
300*	6r	120	51.0a	139.8a	21.2a	6475a

[1]r=residual from 1998 Rice

* The higher N rate treatment included in the analyses since the ANOCOVA analysis for interaction between N uptake (as a proxy to N applied) and P treatment levels was not significant.

Table 67. Lime response, 2000 Corn, Ilagan.

Inputs					
N	Lime	P	N uptake	P uptake	Grain Yield
kg ha^{-1}	t ha^{-1}		---------------- kg ha^{-1} ----------------		
200	0	60	93.1b	12.2b	4258b
200	3r*	60	95.4b	13.5b	4554b
200	6r	60	132.8a	19.2a	5818a

*r=residual from 1998 Rice

Table 68. Soil analysis (0-15 depth) after harvest of the corn crop (Hybrid Cargill 818) planted in an acid upland site in Barangay San Antoni, Ilagan, Isabela, Philippines. 2000 Wet Season.

Lime*	**GM**	**N**	**P**	**K**	**pH**	**Mehlich 1 P**	**OC**	**Exch. Acidity**	**Exch. Aluminum**
	t ha^{-1}		kg ha^{-1}		1:1H2O	mg kg^{-1}	%	cmol$_c$ kg^{-1}	
L0	-	0	0	60	4.42	2.62	1.36	2.47	2.18
L0	-	200	60	60	4.28	14.46	1.52	1.84	1.66
L2	-	0	60	60	6.42	19.12	1.32	0.98	0.92
L2	-	200	0	60	6.07	2.49	1.32	0.02	0.00
L2	-	100	60	60	6.23	23.19	1.26	0.03	0.00
L2	-	200	60	60	6.07	13.20	1.36	0.02	0.00
L2	-	300	60	60	5.81	13.71	1.43	0.02	0.00
L2	-	200	30	60	6.33	10.37	1.21	0.02	0.00
L2	-	300	120	60	5.82	50.96	1.18	0.02	0.00
L2	-	100	30	60	5.92	6.57	1.40	0.02	0.01
L1	-	200	60	60	5.15	9.32	1.29	0.10	0.04
L2	-	200	60	60	5.05	12.28	1.25	0.05	0.02
L0	5	200	60	60	4.39	15.76	1.53	1.80	1.61
L1	5	200	60	60	5.04	10.94	1.45	0.19	0.12

*No lime applied, lime level is based on lime applied on the previous crop.

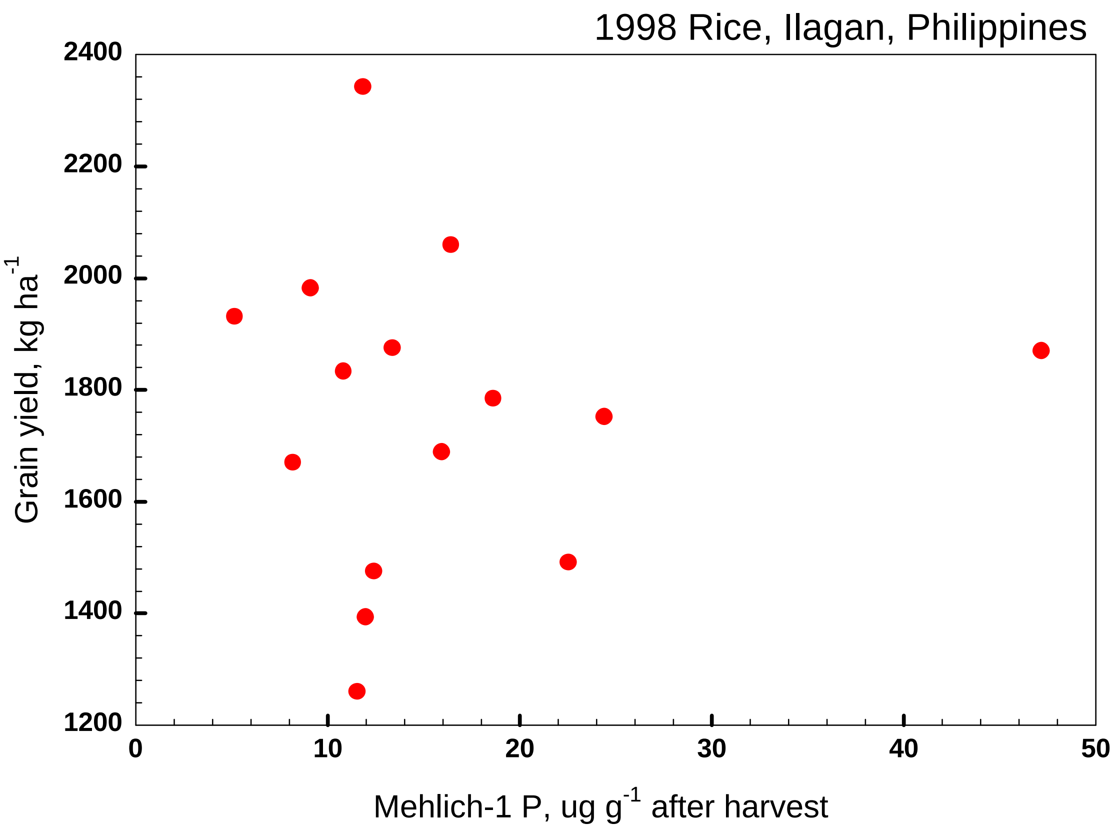

Figure 10. Mehlich 1 P vs. grain yield, 1998 Rice, Ilagan, Philippines.

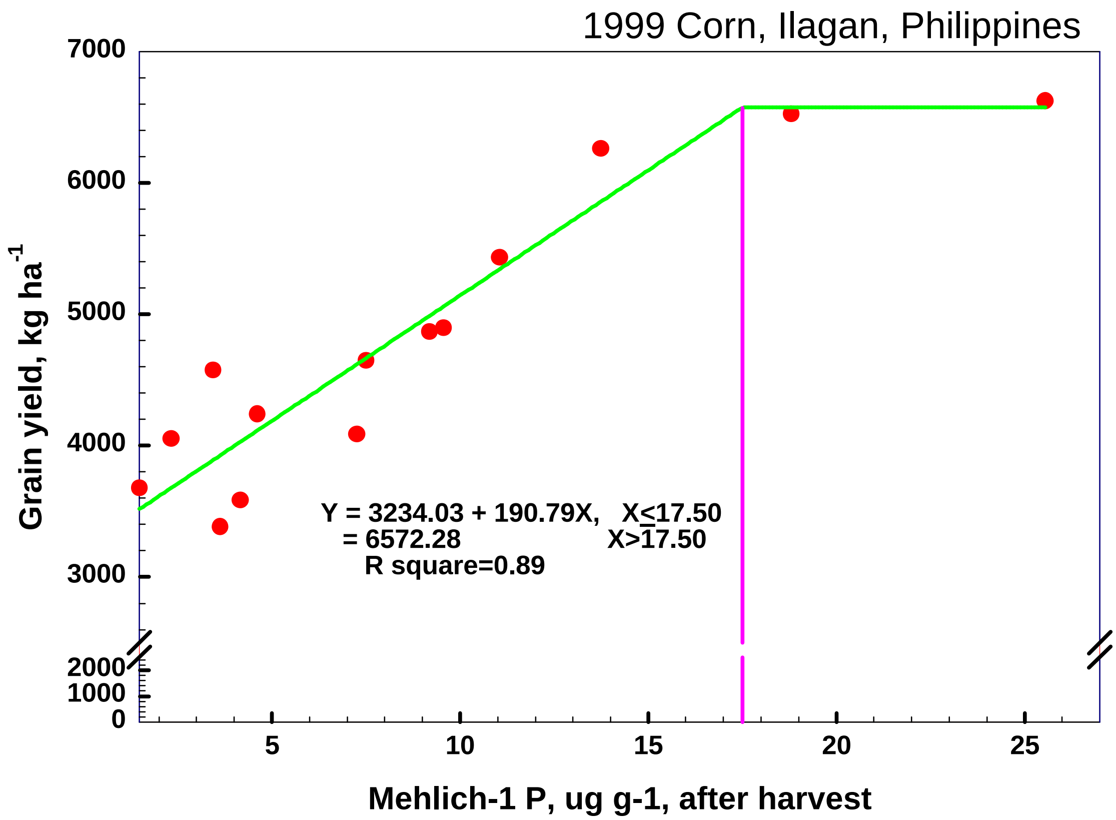

Figure 11. Mehlich 1 P vs. grain yield, 1999 corn, Ilagan, Philippines.

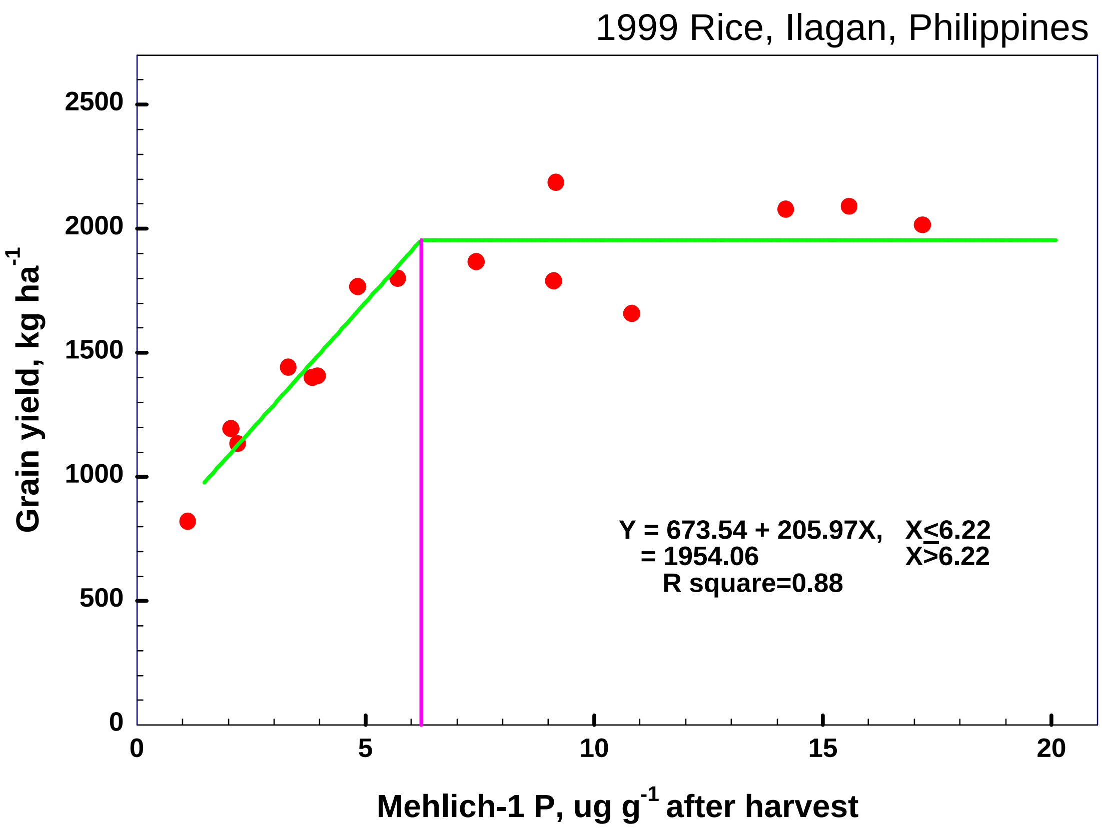

Figure 12. Mehlich 1 P vs rice yield, 1999, Ilagan, Philippines.

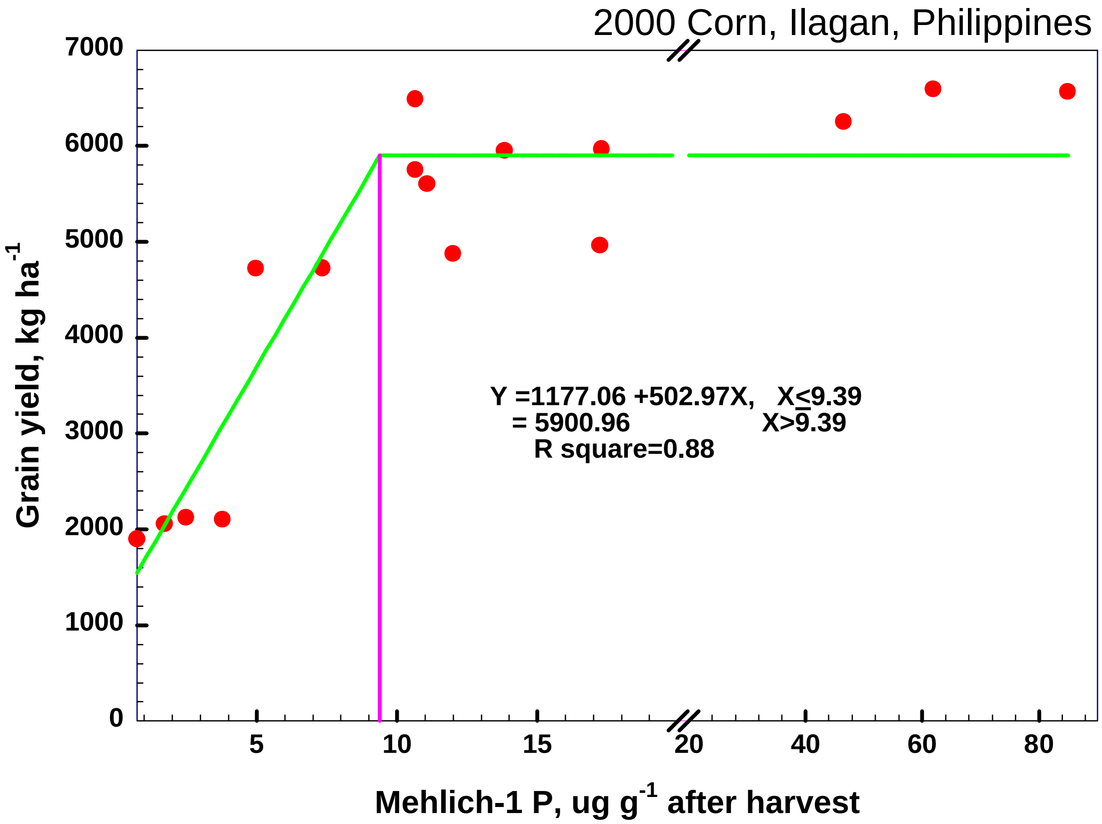

Figure 13. Mehlich 1 P vs. corn grain yields, 2000, Ilagan, Philippines.

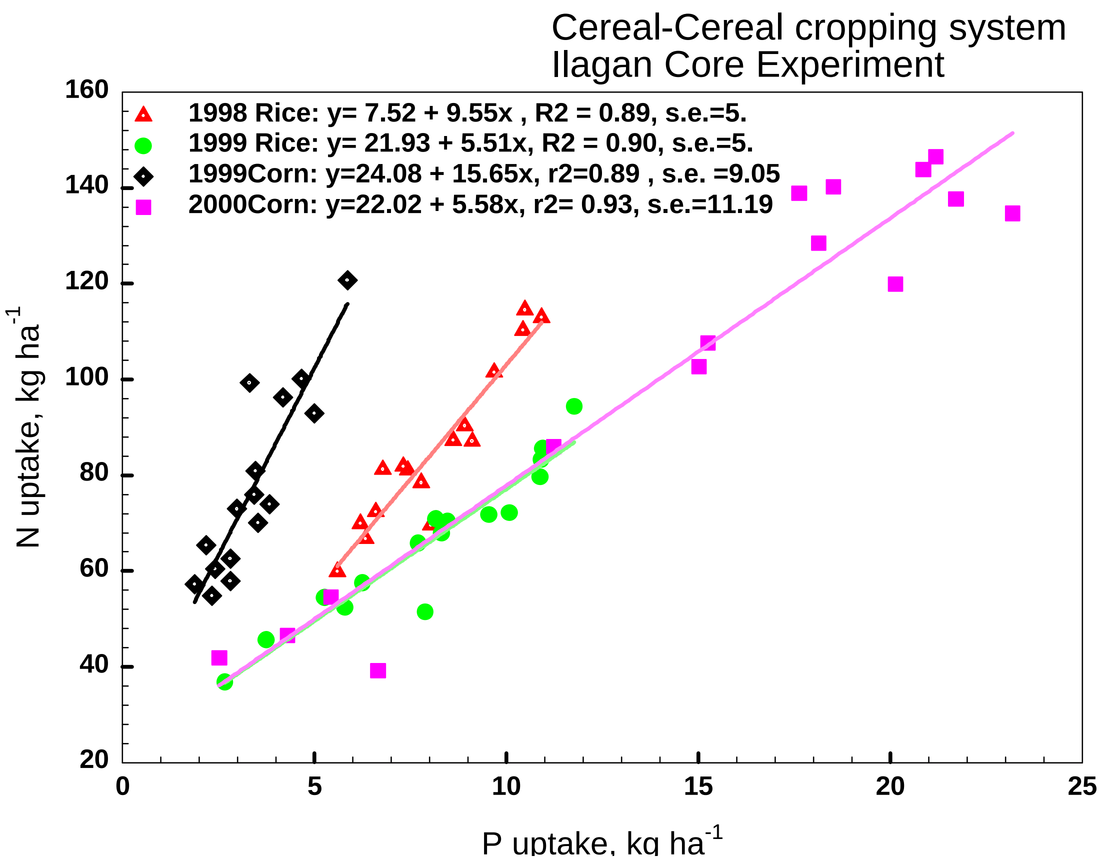

Figure 14. P uptake vs N uptake for 1998 Rice - 2000 corn crops, Ilagan, Philippines.

Table 69. N response, 1999 Peanut, Ilagan.

Inputs					
N	**Lime**	**P**	**N uptake**	**P uptake**	**Grain yield**
kg ha^{-1}	t ha^{-1}			kg ha^{-1}	
0	4.18	60	174.6a	16.8a	1793a
30	4.18	60	168.9a	17.0a	1756a
120	8.37	60	175.6a	16.2a	1797a

Table 70. P response, 1999 Peanut, Ilagan.

Inputs			Mehlich 1 P			
N	**Lime**	**P**	**after harvest**	**N uptake**	**P uptake**	**Grain Yield**
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	ug g^{-1}	----------	kg ha^{-1}	----------
30	4.2	0	2.9c	161.9a	10.5b	589b
30	4.2	30	6.5c	170.4a	14.6ba	1797a
30	4.2	60	14.5b	168.9a	17.0a	1756a
30	4.2	120	22.3a	177.8a	18.0a	1822a

Table 71. Lime response, 1999 Peanut, Ilagan.

Inputs					
N	**Lime**	**P**	**N uptake**	**P uptake**	**Grain Yield**
kg ha^{-1}	t ha^{-1}		---------------	kg ha^{-1}	---------------
0	4.2	120	187.0a	19.7a	1777a
0	8.4	120	185.9a	18.6a	2026a

Table 72. Effect of lime and green manure, 1999 Peanut, Ilagan core experiment.

Inputs				
Lime	**Green Manure**	**N uptake**	**P uptake**	**Grain Yield**
	t ha^{-1}		kg ha^{-1}	
4.8	0	174.6	16.8	1793
0	5	163.0	13.5	1565
4.8	5	196.5	20.6	1992

Table 73. Contrasts for lime and green manure effects, 1999 Peanut, Ilagan core experiment

Contrasts	**Treatment comparisons**	**Mean Differences**		
		Total N uptake	**P uptake**	**Grain Yield**
Effect of lime when green manure is also applied	T15 vs. T14	33.51ns	7.15*	426.57*
Effect of green manure when lime is also applied	T15 vs. T3	21.92ns	3.83*	198.94ns
Lime only vs. green manure only	T3 vs T14	11.60ns	3.32ns	227.63ns

**, significant at 1%, *significant at 5%, ns, not significant

Table 74. N response, soybean, Ilagan, Isabela, 2000.

Inputs					
N	**Lime**	**P**	**N uptake**	**P uptake**	**Grain yield**
kg ha^{-1}	t ha^{-1}		---------------	kg ha^{-1}	---------------
0	4.2r*	50f*+60r	103.5a	5.5a	1732a
30	4.2r	50f+60r	112.6a	6.3a	1836a
135	8.4r	50f+60r	126.0a	6.1a	2044a

*f=freshly applied, r=residual from 1999 Peanut application

Table 75. P response, soybean, Ilagan, Isabela, 2000.

Inputs			Mehlich 1 P				
N	**Lime**	**P**	**at planting**	**after harvest**	**N uptake**	**P uptake**	**Grain yield**
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	ug g^{-1}			kg ha^{-1}	
30	4.2r	0	4.0	1.1	45.8c	2.3c	551c
30	4.2r	25f+30r	4.6	4.3	83.0b	7.8b	1466b
30	4.2r	50f+60r	8.2	6.2	112.6ba	11.4a	1836ba
30	4.2r	100f+120r	12.4	13.0	130.9a	13.6a	2183a

r=residual from 1999 Peanut application

Table 76. 2000 Soybean, Ilagan Lime response

Inputs			Mehlich 1-P			
N	**Lime**	**P**	**after harvest**	**N uptake**	**P uptake**	**Grain Yield**
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	ug g^{-1}	---------- kg ha^{-1} ----------		
0	4.18r	100f+120r	15.5a	133.2a	14.0a	2072a
0	8.37r	100f+120r	18.1a	128.4a	14.2a	2118a

r=residual from 1999 Peanut application

Table 77. Effect of lime and green manure plots 2000 Soybean, Ilagan core experiment

Inputs		Mehlich 1-P			
Lime	**Green Manure**	**after harvest**	**N uptake**	**P uptake**	**Grain Yield**
----- t ha^{-1} -----		ug g^{-1}	---------- kg ha^{-1} ----------		
4.2	0	5.5	103.5	10.1	1578
0	5	4.9	87.9	9.2	1361
4.2	5	7.7	123.6	12.7	1947

Table 78. Contrasts , 2000 Soybean, Ilagan core experiment

	Treatment	**Mean Differences**		
Contrasts	**comparisons**	**N uptake**	**P uptake**	**Grain Yield**
Effect on lime given green manure is present	T15 vs. T14	35.66*	3.49**	586.00**
Effect of green manure given lime is present	T15 vs. T3	20.13*	2.63**	369.13**
Lime only vs. green manure only	T3 vs T14	15.53ns	0.86ns	216.87*

**,,significant at 1%, *,significant at 5%, ns, not significant at 5%

Table 79. N response, 2000 Mungbean, Ilagan

Inputs					
N	Lime	P	N uptake	P uptake	Grain Yield
kg ha^{-1}	t ha^{-1}		kg ha^{-1}		
0	0.5f +4.18r2	60f+50r1+60r2	46.9a	5.0a	1042b
30	0.5f+ 4.18r2	60f+50r1+60r2	60.0a	6.8a	1443a
210	0.5f +8.37r2	90f+50r1+60r2	52.9a	7.1a	1221ab

f=freshly applied, r1=residual from 2000 Soybean, r2=residual from 1999 Peanut

Table 80. P response, 2000 Mungbean, Ilagan

Inputs			Mehlich 1-P				
N	Lime	P	bef. planting	after harvest	N uptake	P uptake	Grain Yield
kg ha^{-1}	t ha^{-1}	kg ha^{-1}	ug g^{-1}			kg ha^{-1}	
30	0.5f+ 4.18r2	0	1.06 b	2.30	19.5b	1.5b	487c
30	0.5f +4.18r2	30f+25r1+30r2	4.28 b	5.80	49.3a	5.2a	908b
30	0.5f +4.18r2	60f+50r1+60r2	6.25 b	9.17	60.0a	6.8a	1443a
30	0.5f +4.18r2	90f+100r1+120r2	13.02 a	16.11	55.4a	6.2a	1301a

Table 81. Lime response, 2000 Mungbean, Ilagan

Inputs					
N	Lime	P	N uptake	P uptake	Grain Yield
kg ha^{-1}	t ha^{-1}	--------------------	kg ha^{-1}	--------------------	
0	0.5f +4.18r2	100r1+120r2	47.5a	5.4a	1105a
0	4.0f +8.37r2	100r1+120r2	55.9a	6.4a	1261a

Table 82. Effect of lime and green manure plots 2000 Mungbean, Ilagan core experiment

Inputs		Mehlich 1 P			
Lime	Green Manure	after harvest	N uptake	P uptake	Grain Yield
----- t ha^{-1} -----		ug g^{-1}	-------------	kg ha^{-1}	-------------
4.8	0	11.00	46.9	45.0	825
0	5	9.12	53.1	5.4	957
4.8	5	11.10	53.5	5.9	907

Table 83. Contrasts, 2000 Mungbean, Ilagan core experiment

	Treatment	Mean Differences		
Contrasts	comparisons	N uptake	P uptake	Grain Yield
Effect on lime given green manure is present	T15 vs. T14	0.38ns	0.53ns	-49.62ns
Effect of green manure given lime is present	T15 vs. T3	6.65ns	0.96ns	81.90ns
Lime only vs. green manure only	T3 vs T14	-6.27ns	-0.43ns	-131.53ns

** significant at 1%, * significant at 5%, ns not significant at 5%

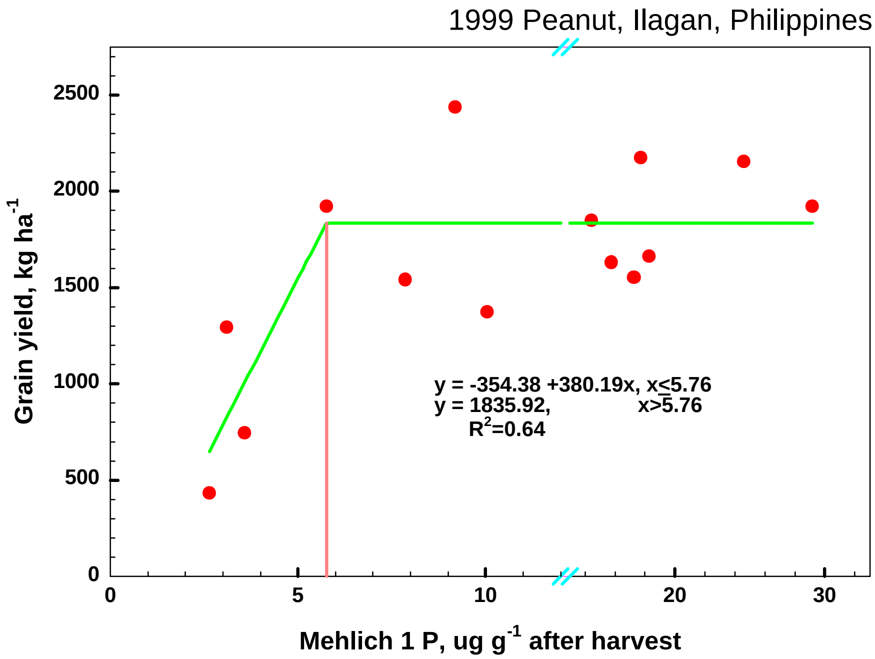

Figure 15. 1999 Peanut response to increasing P level, Ilagan Core Experiment, Philippines.

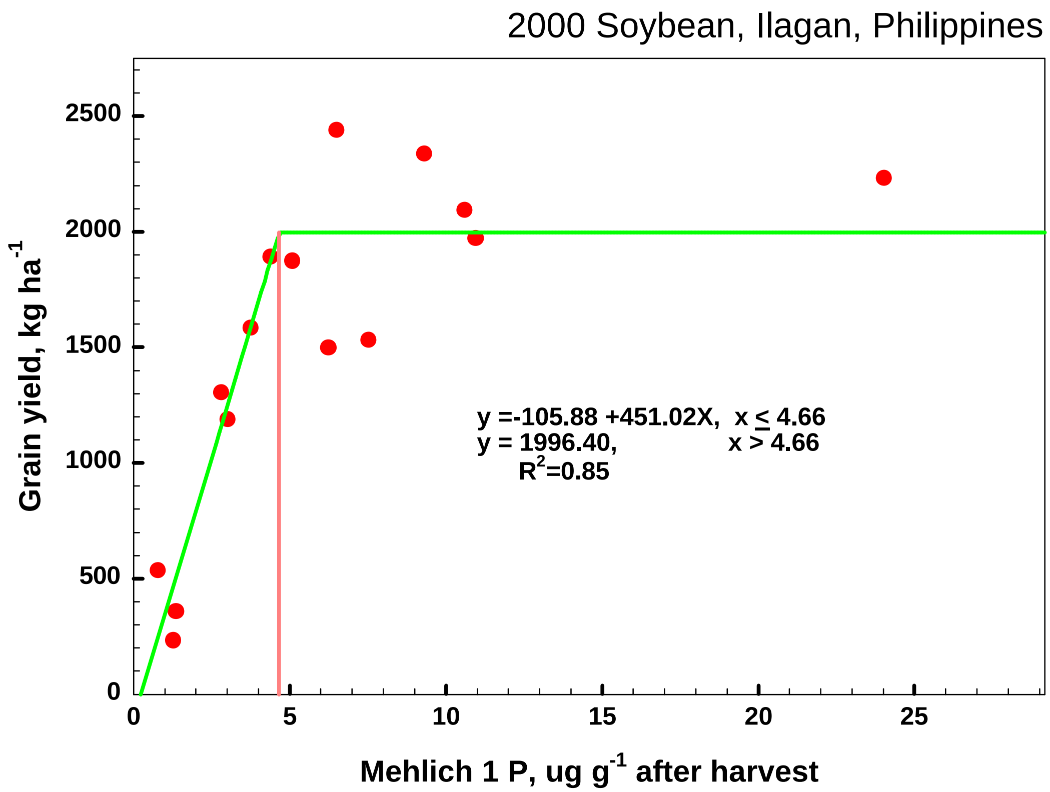

Figure 16. Response of soybean to increasing P level, 2000 soybean experiment, Ilagan, Philippines.

External Funding and Support

- Costa Rica - support in kind from the Univ. Costa Rica in terms of salaries, laboratories and soil/plant analyses, transportation and administrative services are estimated by our collaborators to be $150,000 this year. The agribusiness company DEMASA of Costa Rica and small farmers provided in-kind support by allowing access and harvests of peach palm in their properties. Support in kind from the Ministry of Agriculture, via the 'Los Diamantes' Experiment Station for salaries, experiment maintenance and field supplies/materials are estimated to be $55,000 this year. Local farmer support for the on-farm P fertilization trial is conservatively estimated at $5,000. Total support to the project by collaborators in Costa Rica is conservatively estimated at $210,000.
- Mali - Contributions of time and field and laboratory resources by the Mali collaborators to conduct the research trials, provide the chemical analyses, and perform statistical analysis and interpretation of the data.
- Philippines - Contributions in travel and time costs, experiment establishment/maintenance by IRRI are estimated at$5,000. Time spent by collaborating scientist Dr. Teodula M. Corton (25% of her time). In addition, the use of the laboratory facilities of PhilRice, use of equipment and vehicle for visiting the site. Time also of collaborators from DA-Ilagan Experiment Station (20% of their time).

Travel and Meetings Attended

- Adrian Ares - ASA-CSA-SSSA Annual Meetings, 5 Nov. – 10 Nov., Minneapolis.
- Loyd Hossner - travel to Mali to assist IER collaborators to organize data collected in 1998-1999 and discuss plans for the 2000 crop year. May 22-June 3.
- Jocelyn Bajita - travel to Philippines to conduct field research on diagnosis and alleviation of Mn toxicity in acid upland soils as part of Ph.D. program at the Univ. of Hawaii. May 15-August 22.
- Eloy Molina - travel to Hawaii to work with Univ. Hawaii and N.C. State Univ. collaborators on field and laboratory data for trials in Costa Rica on peach palm nutrient management. July 2-15.
- Frank Hons - travel to Mali to assist IER collaborators in planting experiments for the 2000 crop year and collect pending data from the 1998-1999 crop seasons. August 12-19.
- Adrian Ares - travel to Costa Rica to work with collaborators on soil microbial and organic P analysis, verify allometric relations for peach palm biomass and nutrient accumulation, and measure below ground biomass storage in mature plantations. September 9-24.
- Fred Cox - travel to Costa Rica to work with collaborators on laboratory and field trials related to P management for peach palm; travel to Ecuador to review and discuss soil P management data with Dr. Espinosa (PPI-Potaphos). September 17-18.
- L. R. Hossner and F. M. Hons traveled to the American Society of Agronomy meetings in Minneapolis, Minnesota, to participate in technical meetings and discuss international programs with Soil Management CRSP personnel.
- Thomas George - ASA-CSA-SSSA Annual Meetings, 5 Nov. – 10 Nov., Minneapolis.

Relevant Publications, Reports and Presentations at Meetings

Annual Philippines Research and Development Symposium, 2000, 2001. (National Meeting).

Ares, A. 2000. Report on trip to Costa Rica. Decision Aids for Integrated Soil Nutrient Management Project. 7p. (http://intdss.soil.ncsu.edu/sm-crsp/Download/Trip_Reports/Ares_CRica_0900.pdf).

Ares, A., N.P. Falcao, R.S. Yost, K. Yuyama, E. Molina and C.R. Clement. Soil and foliar nutrient analysis as diagnostic and predictive tools in perennial tree crops. Agron. Abstr. p. 353.

Ares, A., J.P. Quesada, J. Boniche and R.S. Yost. 2000. Allometric relationships for *Bactris gasipaes* Kunth in heart-of-palm production agroecosystems of Costa Rica. Agron. Abstr. p.56.

Ares, A., J.P. Quesada, J. Boniche, R.S. Yost, E. Molina, J. Smyth. Allometric relationships for *Bactris gasipaes* Kunth in heart-of-palm production agroecosystems in Costa Rica. (To be submitted to the Journal of Agriculture Science).

Ares, A., J. Boniche, E. Molina, R.S. Yost (2000). Biomass, nutrients and carbon stores as affected by age and spacing on *Bactris gasipaes* stands for heart-of palm in Costa Rica (To be submitted to Field Crops Research).

Blanton-Knewtson, Sharon. 2000. Nitrogen and phosphorus dynamics in tropical soils of Mali, West Africa. Master of Science Thesis. Texas A&M Univesity. College Station, TX. 173 p.

Cox, F. 2000. Report on travel to Costa Rica and Ecuador. Decision Aids for Integrated Soil Nutrient Management Project. 12p. (http://intdss.soil.ncsu.edu/sm-crsp/Download/Trip_Reports/Cox_TripRpt_900.pdf).

Doumbia, M.D., A. Sidibé, A. Bagayoko, A. Bationo, R. A. Kablan, R.S. Yost, L.R. Hossner et F.M. Hons. 2001. Recommandations Specifiques d'engrais: Calibration et Validation du Module Phosphore de Numass. African Crop Science (in review)

George, T., J. Quiton and R. Yost .2000. Determining critical soil phosphorus levels for upland crops. Poster presented at the ASA-CSA-SSSA Annual Meetings, 5 Nov.- 10 Nov., Minneapolis.

Hons, F. 2000. Report on trip to Mali. Decision Aids for Integrated Soil Nutrient Management Project. 3p. (http://intdss.soil.ncsu.edu/sm-crsp/Download/Trip_Reports/Hons_Mali_0800.pdf).

Hossner, L. 2000. Report on trip to Mali. Decision Aids for Integrated Soil Nutrient Management Project. 2p. (http://intdss.soil.ncsu.edu/sm-crsp/Download/Trip_Reports/Hossner_Mali_0500.pdf).

Kouyate, Zoumana, Kathrin Franzluebbers, Anthony S.R. Juo, and Lloyd R. Hossner. 2000. Tillage, crop residue, legume rotation, and green manure effects on sorghum and millet yields in the semiarid tropics of Mali. Plant and Soil. 225:141-151.

Molina, E., A. Ares, R.S. Yost and T.J. Smyth. 2000. Biomass and nutrient accumulation through time in Bactris gasipaes, Kunth, agroecosystems in Costa Rica. Agron. Abstr. p. 270.

Toure, A., S.B. Coulibaly, M. D. Doumbia, D. T. Rosenow, G.C. Peterson, S. Sidibe, A.B. Onken, and L. R. Hossner. 2001. Sorghum growth in acid soils of West Africa: Genotype screening. African Crop Science Journal. (In Press)

Yost, R., A. Ares. (2000) Nutrient management decision support systems for tree crops. Proc. Symposium on Soil and Site Productivity for Forestry in Hawaii (In press).

Yost, R., A. Ares. (2000) Phosphorus and lime needs of trees in highly weathered soils. Proc. Symposium on Soil and Site Productivity for Forestry in Hawaii (In press).