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SUMMARY

The initial phase of the contract, a review, analysis and interpretation of published literature and other sources of information related to factors limiting crop production on tropical soils, was completed and published during this report period. The world-wide demand of this publication quickly exhausted the printed stock. A second printing in English and a Spanish translation are being prepared. A study on the economics of potato fertilization in relation to soil test recommendations in the highlands of Peru was completed and published. The economists, working in close cooperation with soil scientists, collected additional fertilizer response data from Costa Rica, Colombia, Brazil, Peru and Bolivia for further economic analysis. An improved version of the fertility-capability soil classification system was developed. Agronomic and economic evaluations of it has begun with data from Central America, Brazil and Peru.

During this year, arrangements were finalized for the initiation of in-depth research in (1) Central America (Guatemala and Costa Rica) on the fertility management of volcanic ash soils, (2) The Amazon Jungle (Yurimaguas, Peru) for the improvement of shifting cultivation systems and (3) the Campo Cerrado (Brasilia, Brazil) for the fertility management of Oxisols. Four staff members headquartered at these sites are working in close cooperation with local counterparts and International Soil Fertility Evaluation and Improvement Program personnel. Preliminary findings of practical significance include (1) an improvement on phosphorus soil testing methods for volcanic ash soils in Guatemala, (2) the presence of widespread sulfur deficiency in the highlands of that country, which could become significant as the management level increases, (3) severe initial soil compaction problems and lower fertility with mechanical land clearing in the Amazon Jungle as opposed to the conventional slash and burn method, and (4) indications of a residual effect of previous lime and phosphorus application on highly leached and acid soils of the Campo Cerrado.

LIST OF TABLES AND FIGURES

INTRODUCTION

This project was initiated on July 1, 1970 under a five-year contract with the Agency for International Development, through its Technical Assistance Bureau. The major objective is to provide relevant information to supplement and complement the International Soil Fertility and Improvement Program (AID/la 646) in the Latin American region. The objectives of phase one of this project are to review, analyze and interpret published literature and other sources of information related to soil factors influencing crop production in tropical Latin America and to identify major problems and sites for in-depth research in phase two The objective of phase two is to generate relevant research information to solve some of the principal soil-related problems that limit food production in the Latin American tropics.

The activities during 1972 reflect the completion of the first phase of this contract and the initiation of the second "A Review of Soils Research in Tropical Latin America" was published in July 1972 summarizing the results of phase one The world-wide demand for this publication quickly exhausted the printed stock. A second printing in English and also a Spanish translation will be available in 1973.

The economics personnel completed the study of the economics of potato fertilization in relation to soil testing in the highlands of Peru. This pilot study will be published as a North Carolina Experiment Station Technical Bulletin. The economists, working in close cooperation with soil scientists, obtained additional fertilizer response data from Costa Rica, Colombia, Brazil, Peru and Bolivia for further economic analysis

During this year, arrangements were finalized for the initiation of on-site research in three areas representative of different major ecological regions of the Latin American tropics. They are: the Central American Highlands, the Amazon Jungle, and the Campo Cerrado.

Dr. Robert E. McCollum spent several months in Guatemala initiating field experiments in various regions of this country. This work was conducted in cooperation with the International Soil Fertility Evaluation and Improvement Project (ISFEIP) and the Dirección General de Servicios Agropecuarios of the Guatemalan Ministry of Agriculture.

Mr. Edward J. Tyler and Mr. Christopher E. Seubert arrived in Peru in August 1972 and initiated research on soil characterization and soil management under shifting cultivation at the Yurimaguas Experiment Station in close collaboration with the Peruvian Ministry of Agriculture.

Dr. Donald D. Oelsligle arrived in Turrialba, Costa Rica in August 1972 an assume the position of coordinator of the research activities in the Central American region. Through a sub-contract with the Instituto Interamericano de Ciencias Agricolas, Dr. Oelsligle will work together with IICA scientists, ISFEIP and Ministry of Agriculture staff throughout Central America.

Ing. Enrique Gonzales E. arrived in Brasilia, Brazil in September 1972. He joins Dr. George Naderman of Cornell University in the joint N.C.S.U.-Cornell research project for the Campo Cerrado. The team is headquartered at the Estação Experimental de Brasília in close cooperation with the Direção Naçoal do Pesquisas e Experimentação Agropecuarias of the Brasilian Ministry of Agriculture and the USAID Mission.

These on-site scientists receive frequent assistance and supervision from the Raleigh staff. They also coordinate other contract activities in each country.

In addition to working together with the previously mentioned institutions, the research staff maintains close working relationships with the

ISFEIP and Raleigh staff. The joint meeting of la-646 and csd 2806-supported staff in Guatemala last year has been supplemented by frequent meetings in Raleigh as well as joint travel and work overseas.

The contents of the projects finished during this year have been published in separate covers. This report, therefore will summarize them, describe the organization and approach of the overseas locations and the specific experiments planned for each site.

The following North Carolina State University staff have had major responsibilities in this program:

C. B. McCants, Professor and Head, Soil Science Department.

P. A. Sanchez, Assistant Professor and Project Leader.

S. T. Benavides, Research Assistant. Soil Genesis.

S. W. Buol, Professor. Soil Genesis and Classification.

W. V. Bartholomew, Professor. Soil Microbiology.

B. Batavia, Research Associate. Economics.

S. J. Chang, Research Assistant. Economics.

F. R. Cox, Associate Professor. Soil Micronutrients.

E. Gonzales E., Research Assistant. Soil Fertility (Brasilia).

E. J. Kamprath, Professor. Soil Fertility.

A. S. Lopes, Research Assistant. Soil Fertility.

J. F. Lutz, Professor. Soil Physics.

R. E. McCollum, Associate Professor. Soil Fertility (Guatemala).

D. D. Oelsligle, Visiting Assistant Professor. Tropical Soils (Turrialba).

P. Patrick, Research Technician.

R. K. Perrin, Associate Professor. Economics.

J. C. Ryan, Research Associate. Economics.

C. E. Seubert, Research Assistant. Soil Management (Yurimaguas).

F. Stadler, Secretary.

R. Sprickman, Secretary.

E. J. Tyler, Research Assistant. Soil Genesis (Yurimaguas).

D. L. Waugh, Short-term Consultant (Guatemala).

R. S. Yost, Research Assistant. Soil Fertility (Brasilia).

In addition to these, the ISFEIP staff located in Raleigh and in the host countries have made valuable contributions toward planning and executing the various projects. Specific areas of input are identified in this report. Special recognition is made to Dr. J. W. Fitts, Director ISFEIP, for general counsel and assistance and to Miss Dotty Goodson, Administrative Assistant for guidance on numerous budgetary details.

REVIEW OF SOILS RESEARCH IN TROPICAL LATIN AMERICA

A book with the above title was published in July 1972. Dr. P. A. Sanchez served as editor. It has been distributed throughout the world to interested scientists and agencies. This review compiled over 1000 references and it is divided into the following chapters:

1. Soil genesis, morphology and classification, by S. W. Buol.
2. Soil physical properties, by J. F. Lutz.
3. Soil management under shifting cultivation, by P. A. Sanchez.
4. Soil nitrogen in the tropics, by W. V. Bartholomew.
5. Nitrogen fertilization, by P. A. Sanchez.
6. Soil acidity and liming, by E. J. Kamprath.
7. Phosphorus, by E. J. Kamprath.
8. Potassium, by F. R. Cox.
9. Sulfur, by E. J. Kamprath.
10. Micronutrients, by F. R. Cox.

Each chapter reviewed the accumulated knowledge, evaluated it and pointed out the present soil research gaps most relevant to increasing production of basic crops in the region. The main conclusions were:

Chapter 1. Soils of the tropics are as variable as those in the temperate region. The only unifying characteristic applicable to all tropical soils is their uniform temperature regime. Features of tropical soils are similar or the same as those in temperate zones and can be predicted and interpreted by genesis theories to the same degree as can temperate soils.

The importance of laterite or plinthite formation has been grossly overemphasized in terms of its limited geographical occurence.

Classification of soils in tropical America is fragmented but not as drastically as it would appear at first glance. Officially three major systems are of major use but since these have a high degree of correlation, information can be extrapolated with minimum difficulty. Also, there has been, and is, an intense effort on the part of most Latin American pedologists to become knowledgeable in the U.S. system.

They are hindered by lack of rapid translation and transmittance of recent amendments to this system.

There is an abysmal lack of communication between fertility-economic research and the soil classification and mapping work which affords such research the sound areal extrapolation that is necessary. A need is apparent for improved understanding and cooperation. It appears that a technical soil classification kept simple by using only soil morphology and composition, known and demonstrated to have economic influence on soil-plant-fertilizer interactions will help bridge this abyss.

Chapter 2. Research on soil physical properties has been very limited. Emphasis is needed to seriously tackle soil erosion problems and to interrelate physical with chemical properties in relation to plant growth. This is particularly crucial for the Oxisols, where available moisture and soil fertility are major limiting factors. Continuous cultivation of these soils result in changes in infiltration rate and susceptibility to erosion which deserve careful study.

Chapter 3. A systematic study aimed at developing new management alternatives in shifting cultivation areas is badly needed for the rapidly developing portions of the Amazon Basin where massive migration is occurring from densely populated areas in the Andes and Northeast Brazil.

Studies are suggested on the following topics: fertility requirements for continuous cropping, monitoring the physical and chemical soil changes with time during the cultivation periods, optimum duration of the fallow period, the fertilizer value of ash and the possibility of burning crop residues to reduce the rates of fertilizers.

Chapter 4. Nitrogen is the element most likely to limit crop growth in tropical regions. The needs for research lie in the area of improving the efficiency of available soil nitrogen. Studies are suggested in the following topics: position of nitrogen in the root zone, the influence of water on crop absorption of nitrogen and crop use of nitrogen.

Chapter 5. Substantial nitrogen fertilization research has been conducted in Tropical Latin America, but the amount and quality of information obtained is unbalanced both geographically and in terms of relative crop importance. Beyond simple response curves, extensive information is available for crops such as corn, rice, potatoes and forages only in one or two countries per crop. The lack of data on cassava fertilization is one of the most glaring gaps. The need for substantial nitrogen fixation has not been effective in the region.

More emphasis on the potential use of legumes as a nitrogen source for pastures is badly needed.

In many instances, nitrogen responses were linear. Higher rates should be included in future experiments to obtain better estimates of optimum rates particularly if improved varieties or cultural practices are used. The variation in nitrogen needs with season, moisture stress, soil acidity, lodging susceptibility and other factors need more attention. Nitrogen uptake patterns by several crops are available only in a few locations. There is a need for better estimates of the amounts released by the soil and the efficiency of fertilizer use. There is also a need for experimenting more closely with the main cropping systems used such as upland rather than irrigated rice. This information can be obtained rather quickly with fewer but more carefully controlled experiments.

Chapter 6. The highly weathered Oxisols and Ultisols generally have a pH lower than 5 and an exchangeable aluminum saturation greater than 50 percent. The poorly drained soils of the Amazon Basin have a high exchangeable aluminum saturation in the A horizon. Most volcanic ash soils have a pH greater than 5. Neutralization of exchangeable aluminum by liming increased phosphorus uptake and the yield response to phosphorus fertilizers. Liming of certain newly cleared soils decreased the response to phosphorus fertilizers apparently because of increased availability of soil phosphorus. Phosphorus availability was reduced when the soil pH was raised above 6.7 and crop yields were decreased. Raising the pH of acid Andosols above 5.8 increased phosphorus fixation.

Crop response to liming can in most instances relate to neutralization of exchangeable aluminum and supplying calcium and magnesium. In most instances, if the pH is 5.5 or above very little response to liming will be obtained. Yields of legumes may be increased by liming to pH 6 because of increased availability of molybdenum.

Chapter 7. The highly weathered soils of the tropics, Ultisols and Oxisols, are generally quite deficient in phosphorus. These soils also have a large capacity to fix fertilizer phosphorus. The less crystalline the hydrated oxides of iron and aluminum, the more tightly the phosphorus is held. Soils formed from volcanic ash have a very high phosphorus fixation capacity because the presence of amorphous aluminum silicate (allophane).

Large responses to phosphorus fertilization have been obtained on the highly weathered soils in the tropics. Rates of phosphorus on deficient soils generally giving optimum yields were 100 to 150 kg P_2O_5/ha for corn, soybeans, sugar cane, and forages; 120 to 240 kg P_2O_5/ha for wheat, 120 to 180 kg P_2O_5/ha for potatoes, and 60 kg P_2O_5/ha for rice.

Very little work has been done on the amounts of phosphorus required to bring the soil test values up to optimum levels. There is also a need to study the residual effect of phosphorus from given applications of phosphorus.

Chapter 8. Less research has been conducted on potassium than on soil acidity, phosphorus or nitrogen. Nevertheless, many deficiencies have been shown, and the amount may increase as other limiting factors are removed. Responses to potassium are very much related to the sensitivity of the crop being grown. Sugar cane and potatoes have shown yield responses to potassium in over 50 percent of the experiments reviewed. Corn has responded in about a third of the experiments, whereas response of rice and beans seldom occurred.

A great deal of research still is needed in developing a soil test for potassium. The lack of correlation of yield response and available potassium in the Peruvian potato data is a prime example of this. Some of this lack of correlation may be associated with sample drying. The overall effect may be similar to fixation by illite in temperate regions, but the mechanism in tropical soils is unknown. The porous nature of materials derived from volcanic ash may be involved. Longer extraction periods might be beneficial in such cases.

Another factor that may improve the eventual interpretation of potassium soil tests is the consideration of the cation exchange capacity of the soil. Since the soils are very diverse in the tropical region of Latin America, such a consideration could be very helpful.

Chapter 9. The highly weathered savanna soils in South America are likely to be sulfur deficient particularly where they have undergone repeated burning. Mineralization of organic sulfur may initially supply some sulfur, particularly where the soils are high in organic matter.

Although some volcanic ash soils contain large amounts of organic matter very little organic sulfur is released because of the stable condition of the organic matter. Considerable amounts of sulfate are adsorbed by Latosols and volcanic ash soils. Where large amounts of sulfate have been adsorbed by the soil, plants are able to obtain adequate sulfur.

Response to sulfur fertilization was obtained on Latosols which contained less than 10 ppm SO_4-S extracted with NH_4OAc. Application of 20 to 40 kg S/ha has given maximum response where sulfur was limiting yields.

Chapter 10. An analysis of the information presented in this review on micronutrients indicates that deficiencies of zinc, molybdenum and boron are likely to be encountered in Latin America. Of these, zinc problems occur most frequently with low levels in soils and plants being reported throughout much of the area. A background of information on critical levels in soils and plants is slowly evolving. A soil test that is applicable over the wide range of soil conditions encountered is desperately needed. More than likely the interpretation of this test will need to be based on not only the level of available zinc, but also soil pH, soil and fertilizer phosphorus, and perhaps texture. After such a test is developed, the true status of zinc in this region can be fully surveyed.

Molydenum and boron problems occur more sporadically and thus probably are of secondary importance. Many of the molydenum deficiencies, especially as they exist in the Campo Cerrado of Brazil, might be overcome by applying a higher rate of lime. However, the relatively high cost of lime and the possibility of inducing other problems such as greater zinc deficiency make this impractical. As this marginal level of lime and sufficient phosphorus and potassium are utilized in the old Guyana and Brazilian shield areas it may be expected that many legumes should respond to molydenum. In other locations where often the pH and organic matter level are more favorable, deficiencies are noted less frequently. Use of present soil test metnods, although not calibrated in Latin America, would aid in determining potential problem areas.

Boron deficiencies have occurred in crops grown on highly weathered soils when they were subjected to drought conditions. Soil tests are seldom used for boron, but such data when combined with frequency of expected drought could prove helpful.

Problems reported related to iron, manganese, or copper are not major in the region but could be important locally. In some cases, manganese toxicity has been noted but never when an adequate lime level was established. Also, a few cases of copper toxicity created by mismanagement have been shown.

Increased demand for this publication at the average of five copies per week has exhausted the present stock. Arrangements have been made to reprint it as a North Carolina Technical Bulletin with an initial run of 1500 copies. Many of the suggestions received by Latin American scientists have been incorporated into this edition.

A contract was made with a private translator to prepare a Spanish version, which should be published in 1973.

Judging from the reactions of Latin American soil scientists, and a book review appearing in the Bulletin of the International Society of Soil Science, the need for such a review was great. Its usefulness not only will help orient our research work but also that of other institutions working in this hemisphere.

ECONOMICS OF FERTILIZER RESPONSE

During the calendar year 1972, economic research under this contract was directed primarily toward three areas: further analysis of the economics of potato fertilization in Peru, development and testing of fertilizer recommendation procedures, and the collection of response data from Brazil, Colombia, Costa Rica and Peru. The results of these activities are discussed separately in the following sections. In addition to these strictly economic topics, considerable time was devoted to discussion with other contract workers regarding the experiments and experimental designs to be undertaken at the three field research sites.

Fertilization of Potatoes in Peru

An extensive study of the use of a generalized response function for deriving fertilizer recommendations for Peru was completed in 1971. It was determined that the levels of fertilizer currently being recommended in Peru are somewhat less than those which are estimated to maximize net returns from fertilizer. We attempted to estimate the value of using soil tests from a random sample of 1541 soils tested in Peru. For each soil we compared the net returns to fertilizer using a rate based on soil test results versus the returns using a uniform "blanket" recommendation for all soils. The predicted returns using the soil test information averaged $U.S. 94.00 per hectare more than the returns using a uniform rate on all soils. Thus we concluded that soil test information is indeed valuable in this instance.

We recognize that profit-maximizing fertilizer levels may not be the levels which risk-averse farmers would choose to apply. Little information is available regarding the level of risk aversion of farmers in any part of the world. However, using an estimate of risk aversion based on Australian farmers' behavior, we estimated that such farmers would choose to apply only about 75 percent of the expected profit-maximizing levels, giving up some expected returns in exchange for a reduction in risks.

Another method of approaching the risk-discount problem is to assume that farmers would choose to apply fertilizer only so long as the expected marginal rate of return is at least, say 1.5 times the amount spent, or perhaps higher. The resulting fertilizer rates (on average soil) for marginal rates of return of 50%, 100%, 140% and 400% are shown in the table below.

Table 1. Effect of various marginal rate of return constraints on optimum levels of fertilizer for potato production on an average soil in Peru.

Marginal rate of return	Optimum fertilizer rate $N:P_2O_5:K_2O$	Predicated yield	Net returns to fertilizer	Average rate of return
%	(kg/ha)	(kg/ha)	(US$/ha)	%
0	219:177:111	28100	589	674
50	209:164:108	27920	586	704
100	199:150:104	27700	582	738
140	191:140:101	27490	577	765
400	140: 70: 83	25110	497	971

If farmers should insist upon no less than $1.50 return for the last $1.00 spent on fertilizer, they should apply 209:164:108, which is a reduction of about 5 percent from profit-maximizing levels. On the other hand, they would suffer a reduction in expected net returns of only $2.72 per hectare, about 0.5% of the maximum net returns. The last column in the table shows that an average of $7.04 will be returned (net) for each dollar spent on fertilizer at this rate of application. The last line in the table shows that for an application of 140:70:83 (about 65 percent of the profit-maximizing level), a farmer can expect to net an average of $9.71 on each dollar spent, and on a per hectare basis his total net returns to fertilizer will be $497. Thus these farmers can expect to earn about 85 percent of the fertilizer required for the maximum. Since the risk-aversion analysis suggested that farmers would choose to apply only about 75 percent of profit-maximizing levels, it seems reasonable to conclude as a rule of thumb to recommend only about 70 percent of the fertilizer rates needed to maximize expected net returns on potatoes in Peru, in which case they could expect to earn about 88 percent of the maximum achievable net return to fertilizer.

Evaluation of Alternative Recommendation Procedures

The generalized quadratic response function was used to derive recommendations for potatoes. This procedure seemed to work well statistically, but two clear issues remained to be explored. First, how general should a generalized function attempt to be? We had used a single function to represent response in all of the Sierra region of Peru. It would be useful to know whether more accurate predictions can be obtained with functions fitted to each of several more homogenous soil groupings. Considerable effort was expended during 1972 in an attempt to derive statistical and economic criteria which could be used to determine the usefulness of the proposed soil fertility capability classification system as a method of grouping soils. Very preliminary results have indicated that the classification criteria which apply in this case do indeed result in fertilizer response prediction which are better by statistical criteria. This question will be explored further in 1973 using the potato response data as well as others.

The second issue which remained to be explored is how well the generalized quadratic response function (GQRF) predicts optimum fertilizer dosages, compared to other available procedures. The ultimate test for any competing theories is the ability of the theories to predict results in new situations. As an initial test of the GQRF, we compared its ability to predict results on 22 new experiments with that of the current recommendations procedures used by the soil testing laboratory, La Molina, Peru. Prior to observing the experimental results at the 22 new sites, recommendations were generated by the GQRF and by current procedures, using soil test results for the sites. The experimental results at each site were then analyzed to determine which of the treatments resulted in the greatest profit. In eleven cases, the GQRF recommendations were closest to the best treatment, in ten cases the current recommendations were closest to the best treatment, and in one case the two recommendations were identical. This was admittendly a crude test, but it provided some evidence that the GQRF procedure is at least as good as current practice.

More adequate tests have now been devised, and will be employed in the coming year. The GQRF procedure is to be compared with Leibig-type response analysis in their ability to predict optimum treatments for experiments which were not included in the data used to generate the recommendations. Other recommendation procedures may also be considered in the test. The test will be applied to various crops in Peru, Bolivia, Colombia, Costa Rica and Brazil, to provide a wide basis for drawing conclusions as to the suitability of the alternative procedures.

Collection of Existing Response Data

During calendar year 1972, considerable data was obtained from corn and rice experiments in Costa Rica. In addition, arrangements were made for the forwarding of data for potatoes and corn from Colombia and for corn and beans from Brazil. Suitable sets of data on rice response in Peru and wheat response in Bolivia were also made available. Thus it appears that data will be available in Raleigh during 1973 in sufficient quantity to pursue the economic research objectives outlined in the work plans.

FERTILITY CAPABILITY SOIL CLASSIFICATION SYSTEM

The rationale guiding the development of a technical soil classification designed for the expressed purpose of grouping soils with similar fertility management properties has been stated in the 1971 Annual Report, p. 44-50. This remains unchanged.

Reflections on the format of the system along with preliminary testing of the groupings has lead to some changes in the way the system is structured.[1/]

The primary restructuring comes about because of a recognized need to place greater emphasis on the nature of the plow zone when considering management-fertility problems in the production of most crops. Therefore, the texture of the plow layer or 20 cm depth, whichever is shallower, is now taken as the primary criteria for setting the type or highest taxa in the system (Table 2).

A need to recognize changes in texture, or the presence of root restrictions, within the top 50 cm of the soil is considered to be of import. To do this, a second level grouping, substrata type, is established.

The subclasses proposed in the 1971 report have been modified to some extent and are used as condition modifiers to express specific conditions which require consideration in the fertility management of that soil.

[1/] Appreciation for suggestions in extended to Drs. J. L. Walker, E. J. Kamprath, F. R. Cox, R. E. McCollum and P. A. Sanchez of North Carolina State University and Dr. J. K. Coulter of Rothamsted Experiment Station.

Table 2. Criteria for the Fertility Capability Soil Classification System

TYPE[1/]

L = loamy soils: <35% clay but not loamy sand or sand
C = clayey soils: >35% clay
S = sandy soils: loamy sand or sand (USDA)
O = Organic Soil: >30% o.m. to a depth of 50 cm or more

SUBSTRATA TYPE[2/]

L = loamy soil: texture as in type
C = clayey soil: texture as in type
S = sandy soil: texture as in type
R = rock or other hard root restricting layer

CONDITION MODIFIER[3/]

e = (exchange): CEC by Σ bases + unbuffered Al <3; Σcations @ pH7 <7; Σcations + Al + H <10 meq/100mg soil
v = (vertic): very sticky, plastic clay; COLE > 0.09; >35% clay and >50 2:1 expanding clay
x = (x-amorphous clay): pH > 10 in 1N NaF; or positive to field NaF test
a = (Al toxic): >60% of CEC is Al within 50 cm of surface
h = (acid): 10-60% of CEC is Al within 50 cm of surface
i = (iron): Free Fe_2O_3/clay >0.20
Ca = ($CaCO_3$): Free $CaCO_3$ within 50 cm
k = (Potassium): <10% weatherable minerals in 20-2000u fraction within 50 cm
Na = (sodium): >15% of CEC is Na within 50 cm
s = (Salt): > 4 mmhos/cm^2@ 25° within IM
g = (gley): mottles ≤ 2 chroma within 60 cm of surface
d = (dry): ustic or xeric environment; dry > 60 days per year
c = (cat clay): pH in I:I H_2O < 3.5 after drying; Jarosite mottles with hues 2.5 Y or yellower and chromas 6 or more within 50 cm; H_2S odor in field often sufficient

FOOTNOTES:

1/ Texture is average of plow layer or 20 cm depth, whichever is shallower

2/ Substrata type modifier is used if a textural change or hard root restricting layer such as rock is encountered within 50 cm

3/ Condition is present in plow layer or 20 cm, whichever is shallower unless otherwise specified.

This format is being presently evaluated by the use of data from Central America and Brazil collected by Drs. J. L. Walker and R. B. Cate, respectively, of ISFEIP. Dr. Cate is in the process of classifying all the modal profiles of the Brazilian soil survey (approximately 600) into this system. As mentioned in the economics section, this system is also receiving an economic evaluation using Peruvian potato data.

RESEARCH IN CENTRAL AMERICA

Objectives and organization

The Central American Highlands, and similar areas of Mexico and South America are characterized by high-population density farming in soils affected by volcanic ash in various degrees. It is also an area where the International Soil Fertility Evaluation and Improvement Program (ISFEIP) has been particularly active. As a consequence of this activity several questions requiring research attention have arisen.

The initial activities of the Contract started in Guatemala at the request of Dr. J. L. Walker of ISFEIP, the Guatemalan Ministry of Agriculture and the USAID Latin American Bureau. A nutrient element deficiency survey was conducted by Dr. Sanchez, Dr. Walker, and Ings. Luis Estrada, Jaime Wyld and Ramiro Pazos of DIGESA in September 1971. Dr. D. L. Waugh was assigned by this Contract to Guatemala for a three month period in late 1971 to determine areas of research and initiate some of it. During 1972, Dr. R. E. McCollum spent a total of four months planning and executing experiments jointly with ISFEIP and DIGESA personnel. Dr. McCollum's inputs have had a major impact in the limited soil research capability of this country. Continuing support of this nature to Guatemala will continue in 1973.

In March of 1972 at the suggestion of the USAID Latin American Bureau, arrangements were made with the Instituto Interamericano de Ciencias Agri-colas (IICA) at Turrialba, Costa Rica to place a senior soil scientist funded by this contract at the Institute to coordinate and execute research projects throughout the Central American region. A subcontract was made with IICA to provide logistical and administrative support.

Dr. Donald D. Oelsligle, an energetic and experienced soil scientist in Latin American scene was employed as leader for this phase and arrived on site with his family in August. Dr. Oelsligle is working cooperatively with

IICA soil scientists in areas and crops of mutual interest, with the Ministries of Agriculture of the region in crops such as rice or corn which are outside of IICA's present interest and with ISFEIP personnel on research questions raised in the course of their soil testing work. Dr. Oelsligle holds the title of "Resident Scientist" at IICA which enables him to use all the Institute's facilities and advise some of their graduate students on problems of mutual interest.

The enthusiastic support and cooperation of IICA's administrations and soil scientists has helped Dr. Oelsligle to move quickly in the initial phases of his research during this year.

Survey of Nutritional Disturbances in Guatemala

The purpose of this study was to identify which nutritional deficiencies are encountered by Guatemalan farmers who are already applying NPK fertilizers according to ISFEIP recommendations. Soil and plant samples were collected at appropriate locations in one site in the Pacific Coast (Cuyuta) and 11 sites in the Quezaltenango-Totonicapán-Panajachel-Chimaltenango area of the Altiplano. All sites were affected by volcanic ash and probably belong to the suborder Andepts. The topsoil analysis appears on Table 3 with available phosphorus and zinc determined by the dilute-acid extraction procedure.

All upland rice experiments at the Cuyuta Station (site 1) were suffering from chlorosis of younger leaves. Tissue analysis (Table 4) indicates an extremely high copper concentrations (170 ppm), accompanied by relatively low levels of iron, manganese and zinc. The visual symptoms are typical of areas formerly in banana plantations which received high applications of Bordeaux mixture, a fairly common situation throughout Central America. Ings. A. Cordero and A. Romero of the Costa Rican Ministry of Agriculture have observed even higher copper levels in rice tissue and estimate that about 50 percent of the present rice area in

Costa Rica is affected by this disturbance. Varietal differences in the degree of symptom manifestation were observed; Nilo 3 showed the least and IR5 the most. The yields reported by Ing. Ramiro Pazos confirmed this observation. Nilo 3 yielded 4.1 ton/ha while IR5 yielded 2.7. When the disturbance is most severe the plants die within the first month. A research project is being planned for next year to study this problem.

In the Altiplano area, nitrogen was deficient in corn plants (Table 3) only in sites 7 and 12. Phosphorus was deficient early in site 4. Plant potassium contents were above the critical level in all crops. With the above exceptions, the recommended fertilizer rates and/or native fertility apparently eliminated major element problems.

Calcium may have been deficient in oat seedlings on site 5, where the Totonicapán soil had a pH of 4.9. The low pH and possibly aluminum could have inhibited calcium uptake. Magnesium deficiencies in corn are probable at site 3, in oats at site 5, and in wheat at site 6. In site 5, the exchangeable K/Mg ratio was lower than one, suggesting a possible imbalance.

Sulfur deficiencies in corn appear probable in sites 4, 6, 7 and 8 (Quezaltenango, Camanchá and Tecpán series). Wheat intercropped with corn in site 6 showed adequate sulfur levels. Zinc appeared to be deficient in corn on sites 6, 10 and 11. Wheat intercropped with corn on site 6 did not show zinc deficiencies. There is an association between ear leaf Zn levels and soil pH (Fig. 1).

This study led to the inclusion of sulphur and zinc as additional variables in the first set of coordinated fertilizer trials which began in 1972.

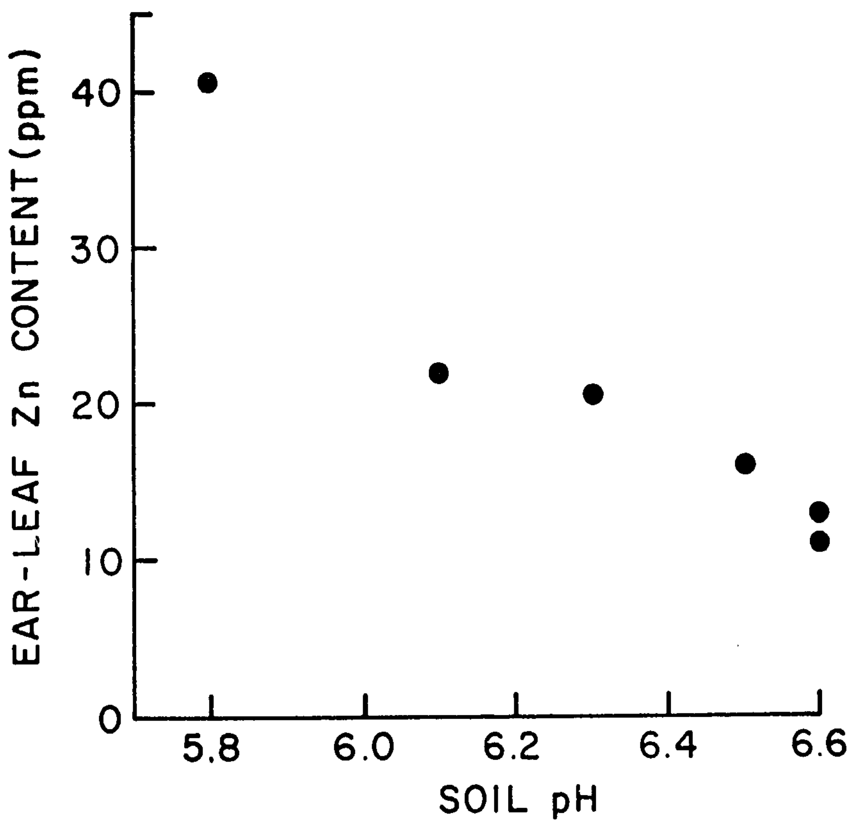

Fig. Relationship between soil pH and zinc content of corn leaves in the Altiplano of Guatemala.

Table 3. Characteristics of topsoil (0-15 cm) samples from micronutrient survey in Guatemala.

Site	Location	Soil series	pH	P ppm	Zn ppm	Ca (meq/100g)	Mg (meq/100g)	K (meq/100g)
1	Cuyuta Exp. Sta.	Tiquisate	6.7	1.6	1.87	15 00	3.12	0.87
2	Quezaltenango Exp. Sta.	Quezaltenango	5.5	13.2	1.29	5.00	0.54	0.92
3	Quezaltenango Exp. Sta.	Quezaltenango	5.5	11.2	1.69	5 00	0.60	1.00
4	Quezaltenango Exp. Sta.	Quezaltenango	5.9	4.8	1.60	6.00	0.91	0.59
5	Palin, Totonicapan	Totonicapan	4.9	1.6	5.00	5.00	0 42	0.51
6	Km 182	Camanchá	6.6	1.2	1.05	9.25	2.69	0.85
7	La Canoa	Tecpán	6.3	5.6	1.75	8.75	1.35	0.92
8	Vista Bella	Tecpán	6.1	1.6	1.56	8.00	1.77	0.74
9	Vista Bella	Tecpán	5.6	3.2	2.29	9.75	2.06	0.97
10	Chimaltenango Exp. Sta.	Alotenango	5.9	9.6	1.27	5.50	0.78	0.33
11	Chimaltenango Exp. Sta.	Alotenango	6.6	8.0	1.44	5.50	0.84	0.44
12	Km 58	Cauqué	6.4	11.2	3.42	9.75	2.54	1.20

Table 4. Plant nutrient status of samples collected in micronutrient survey of Guatemala.

Site	Crop	Tissue	% N	% P	% K	% Ca	% Mg	% S	ppm Mn	ppm Cu	ppm Zn	ppm Fe
1	Rice	Youngest leaf	2.55	0.20	2.6	0.24	0.15	0.21	14.1	170.0	15.6	47
2	Wheat	Youngest leaf (No P)	3.98	0.33	lost sample			0.31	lost sample			
3	Wheat	Youngest leaf (High P)	4.34	0.31	3.3	0.35	0.10	0.40	28.6	6.4	26.4	76
4a	Corn	Youngest leaf	2.63	0.30	2.3	0.31	0.11	0.15	25.2	6.0	19.2	60
4b	Corn	Ear leaf	2.88	0.32	1.7	0.64	0.18	0.15	34.6	5.6	40.6	98
5	Oats	Seedlings	4.42	0.17	4.0	0.23	0.11	0.25	77.8	11.0	24.0	146
6a	Wheat	Youngest leaf	3.56	0.35	3.2	0.20	0.11	0.27	32.8	8.6	24.0	64
6b	Corn	2-3 youngest leaves	2.27	0.27	2.8	0.48	0.21	0.12	47.6	9.2	14.2	244
6c	Corn	Ear leaf	2.49	0.26	2.2	0.65	0.25	0.11	49.6	11.0	13.6	238
7a	Corn	Most recently mat. leaf	1.68	0.18	1.7	0.76	0.15	0.10	16.8	4.0	16.2	64
7b	Corn	Ear leaf	1.82	0.23	2.0	0.56	0.14	0.12	17.0	4.8	20.6	50
8a	Corn	Most recently mat. leaf	2.80	0.34	2.0	0.34	0.13	0.13	54.4	7.6	39.8	68
8b	Corn	Ear leaf	2.69	0.25	1.6	0.63	0.14	0.20	89.2	7.0	22.0	104
9	Wheat	Most recently mat. leaf	3.58	0.28	1.8	0.53	0.14	0.27	68.2	7.2	27.9	59
10	Corn	6th mat. leaf (No P)	3.25	0.23	2.3	0.54	0.14	0.19	22.4	23.0	12.2	104
11	Corn	6th mat. leaf (High P)	2.24	0.20	2.2	0.56	0.14	0.15	19.4	6.4	11.0	78
12	Corn	Ear leaf	1.54	0.24	2.0	0.39	0.22	0.14	19.6	4.2	16.0	92

Soil Test Correlation

Dr. D. L. Waugh compared different soil extraction methods for phosphorus using soils from different Central American countries. He found that the presently used dilute-acid extraction (North Carolina method) tends to overestimate available phosphorus levels in many volcanic ash soils and produce erroneous recommendations. He attributes this to the possible presence of apatite in such soils and found that the bicarbonate (Olsen) extraction produced more reliable results. For example, in a comparison between the two extractants in 100 soils that gave "high" results for phosphorus with the North Carolina method, only one third showed "medium" or "high" values with the Olsen procedure. This conclusion is similar to Dr. Waugh's previous findings with soils from the Peruvian Andes.

A number of methodological problems of adapting these techniques to the existing resources at the soil testing laboratory in Guatemala were also solved. These results will enable the ISFEIP program in Central America to predict phosphorus deficiency more accurately. A continuation of this work is presently being carried out by Ing. Julio Brolo under the supervision of Drs. R. E. McCollum, and J. L. Walker.

Fixation studies using the Olsen-EDTA extraction gave similar results to the North Carolina extract in all "low" P soil. In some soils previously considered "high" in phosphorus, P fixation was observed. In all cases 200 to 300 ppm of added P was sufficient to obtain 30 ppm P with the Olsen-EDTA extraction.

Cooperative Fertilizer Response Trials

A joint project was initiated during the year with the purpose of determining the actual fertility requirements of major crops in the Pacific Coast and Altiplano through a large number of field experiments. This project involves practically all the resources and time of the Guatemalan soil scientists, the ISFEIP staff and 15 Peace Corps Volunteers especially trained for this purpose. Most of Dr. McCollum's time was spent initiating and conducting a number of these experiments and training the Peace Corps Volunteers to do the same. During the rainy season, a large number of experiments were planted on soils with widely ranging nutrient levels. Of these, about 50 should provide reliable data on responses to nitrogen, phosphorus, potassium, and in 25 to sulfur and zinc also. The crops studied were wheat,potatoes, sorghum, rice and sesame. In the Altiplano, the greatest visual response was to phosphorus. On the Pacific Coast response was apparent to both nitrogen and phosphorus. The results are not available at the time of preparation of this report.

Phosphorus Management Studies at the Quezaltenango Station

Phosphorus management is probably the main fertility problem in the Altiplano. A long term experiment consisting of three levels of soil phosphorus and three of applied phosphorus was installed at the Labor Ovalle Station in June, 1972. Wheat was the first crop, planted and will be followed by corn. A similar experiment may be installed at two additional sites in Guatemala.

Nitrogen Management Experiment in the Pacific Coast of Guatemala

An experiment designed to evaluate different timing and rate combinations in a sorghum-sesame rotation was installed at the La Máquina farm during 1972. Unusually dry weather during the germination period caused a poor stand. The experiment will be reseeded again, and barring additional disasters, it should start providing information on nitrogen movement, uptake and efficiency of utilization in 1973.

Multiple Cropping Trials in Costa Rica

Plans are in the advanced stage to initiate multiple cropping trials in the highlands of this country under udic (no dry season) and ustic (strong dry season) climates. The experiments will compare a series of soil management and fertility variables designed to maximize the number of crops per year and of food production in areas where farmers usually grow one crop per year without irrigation.

RESEARCH IN THE AMAZON JUNGLE

Objectives and Organization

About 45 percent of the potentially arable and grazing land in the tropics is presently managed under shifting cultivation, mostly in forested areas. Much of the potential for increasing food production in the tropics, as expressed in a recent report by the National Academy of Sciences, lies in these regions. Shifting cultivation is a fairly efficient system of subsistence farming in areas with low population density As the population of these areas increases, due to the opening of new roads or other reasons, the system breaks down. Such changes are now beginning to take place in the Amazon Basin particularly with the construction of the "Transamazónica" and "Perimetral" highways in Brazil and the Carretera Marginal in Peru, as well as oil discoveries in the jungle of Ecuador and Peru. When settlers from the impoverished, highly populated areas of the Andes and Northeast Brazil move into these areas, they obtain good crop yields during the first year after clearing the forest, but this is followed by progressively lower yields as the soil fertility is quickly depleted. Extensive travel through the area as well as a thorough search of the literature has provided no evidence of systematic research being conducted on this subject.

Since the beginning of the contract, a search has been made for a suitable site to conduct shifting cultivation improvement research with representative soil, climatic and agricultural conditions for the region. Characterization studies were conducted in Peru and Colombia and compared with published data and travel in Brazil. The Yurimaguas area of Peru was selected for this purpose. A formal agreement was signed with the Dirección General de Investigaciones Agropecuarias of the Peruvian Ministry of Agriculture for cooperative research at an expanded site of the Subcentro Regional de Investigaciones Agropecuarias de Yurimaguas.

The agreement was signed on June 23, 1972 and our research staff arrived in August 15, 1972.

Soil Characterization Studies

As part of the selection process of the area in general and the experiment station site especifically, valuable information was obtained on the properties of the major soils of the Upper Amazon Basin of Peru and Colombia by Drs. S. W. Buol, P. A. Sanchez and S. T. Benavides. Eleven soil profiles were collected in the Yurimaguas area; five around Iquitos and the Napo River in Peru and nine throughout the Colombian Jungle from Miraflores to Leticia.

The principal well-drained soils around Yurimaguas and Iquitos are Typic Paleudults (Red Yellow Podzolics) with kaolinitic mineralogy. The imperfectly and poorly drained soils are Tropaqualfs or Tropaquepts (Low Humic Gleys) with abundant amounts of montmorillonite in the gleyed horizon. Spodosols (Tropical Podzols) are found in less extensive areas with coarser parent materials. Mollisols and other high-base status soils are found in the flood plains of the major rivers. Similar properties were observed in that part of the Colombian Amazon jungle located outside of the influence of the Guyana Shield. These sites located in the Guyana Shield classified as Inceptisols grading into Oxisols. Representative profile data appears in Table 5 for the Udults, Table 6 for the aquic soils and Table 7 for the Spodosols. Further travel and study of Brazilian publications of the Manaus and Belem areas indicate that Ultisols also predominate in these areas. The Spodosols and other coarse-textured soils are abundant at Manaus while plinthite deposits occur in localized areas in Belem.

These results suggest that the main soils of the Amazon Basin are not Oxisols as traditionally classified and as they appear in the recently published map of the "Soils of the Humid Tropics" and the FAO World Soil Map.

Table 5. Characteristics of some representative well-drained soils of the Upper Amazon Basin.

Profile No.	Horizon		Sand	Silt	Clay	pH	O.M	Exchangeable Al	Ca	Mg	K	Na	CEC (sum)	CEC of Clay	Base Satn	Silicate Clay Minerals 1/
		cm	%	%	%		%	meq/100g							%	
Y-4	A1	0- 30	57	20	23	3.4	2.8	3.0	5.2	0.1	0.16	0.08	8.5	37.1	65	K3, M^{tr}
	B21	46- 90	53	16	31	3.5	1.1	4.5	1.0	0.1	0.04	0.06	5.7	18.4	21	K3, M^{tr}
	B22	90-113	53	10	37	3.6	0.9	4.7	0.6	0.1	0.04	0.08	5.5	14.9	15	K3, M^{tr}
	IIB23	123-210+	17	20	63	3.8	0.5	15.1	0.6	0.1	0.24	0.08	16.2	25.7	6	K3, M^{tr}
Y-10	A1	0- 5	60	28	12	3.6	4.0	1.9	1.0	0.4	0.26	0.08	3.6	29.3	48	K3, M1, Mi1
	A21	5- 40	44	36	20	4.2	1.1	4.2	0.2	0.1	0.16	0.04	4.7	23.0	11	K3, M^{tr}, Mi1
	A22	40- 60	48	28	24	4.1	0.8	4.5	0.4	0.1	1.20	0.04	6.2	25.6	28	K3, M1, Mi^{tr}
	B1	60- 90	40	36	24	4.2	0.6	6.0	0.2	0.1	0.18	0.02	6.5	26.8	8	K3, M1, Mi^{tr}
	B2	90-140+	44	26	30	4.0	0.4	6.1	0.2	0.1	1.92	0.02	8.4	27.5	27	
I- 2	A1	0- 16	34	36	30	4.0	4.2	5.9	1.0	0.2	0.20	0.10	7.4	24.7	20	K3, V2
	B1	16- 35	30	30	40	4.5	1.8	6.7	0.4	0.1	0.08	0.10	7.4	18.4	9	K3, V2
	B21	35- 70	20	26	54	4.3	0.9	9.5	0.2	0.1	0.08	0.04	9.9	18.4	4	K3, V2, Intl
	B22	70-100	20	26	54	4.5	0.6	11.6	0.2	0.1	0.06	0.04	12.0	22.2	3	K3, V2, Intl
	B23	100-150	20	34	46	4.5	0.6	10.9	0.2	0.1	0.08	0.04	11.3	24.6	4	K3, V2, Mi1
	C1	150-240	52	20	28	4.7	0.4	5.4	0.2	0.1	0.08	0.04	5.8	20.6	7	K3, V2, Mi1
	C2g	240-250+	24	36	40	4.6	0.3	9.0	0.7	0.1	0.08	0.04	9.5	23.7	4	K3, V2, Mi2

1/ K = kaolinite M = montmorillonite, Mi = mica, V = vermiculite, Int = 2:1 - 2:2 integrade, tr = trace
1 = present, 2 = 10-50%, 3 = more than 50%.

Table 6. Characteristics of some representative less well-drained soil profiles of the Upper Amazon Basin.

Profile No.	Horizon		Sand	Silt	Clay	pH	O.M.	Exchangeable Al	Exchangeable Ca	Exchangeable Mg	Exchangeable K	Exchangeable Na	CEC (sum)	CEC of Clay	Base Satn	Silicate Clay Minerals[1]
		cm	%	%	%		%	meq/100g							%	
Y-2	A1	0- 9	67	18	15	4.4	1.9	0.0	3.6	0.2	0.16	0.16	4.2	27.8	99	K3, M1
	A2	9- 20	61	20	19	4.4	1.4	0.1	5.2	0.2	0.16	0.18	5.8	30.7	98	K3, M1
	B21	20- 43	55	10	35	3.9	1.0	5.9	6.4	0.3	0.16	0.20	13.0	37.2	54	K3, M1
	B22g	43- 83	63	8	29	3.5	0.5	6.1	3.0	0.1	0.18	0.16	9.6	33.0	36	K3, M1
	Cg	83-160+	25	28	47	4.5	0.5	27.2	18.2	0.4	0.64	0.46	46.9	99.9	42	M3, K1
Y-7	A1	0- 5	23	32	45	5.5	4.6	0.5	14.0	5.5	0.72	0.36	21.1	45.9	97	M2, K2, Mi1
	B21g	5- 25	18	26	55	4.9	1.3	9.2	10.8	6.5	0.66	0.38	27.5	49.2	67	M2, K2, Mi1
	B22g	25- 80	18	28	53	5.0	1.1	12.5	9.0	6.0	0.42	0.42	28.3	52.5	56	M2, K2
	B23g	80-100+	24	12	63	5.2	0.7	14.5	10.4	7.3	0.44	0.68	33.4	52.1	56	M3, K1, Mi tr
I-1	A	0- 5	28	36	36	5.6	7.9	0.0	12.8	3.4	0.36	0.16	16.7	46.4	100	
	A2g	5- 10	19	21	60	4.7	2.1	5.5	8.6	3.5	1.56	0.16	19.3	32.2	72	
	B21g	10- 50	19	21	60	4.6	1.1	14.6	20.0	1.3	0.44	0.08	18.4	30.7	21	
	B22g	50- 90	18	2	80	4.7	0.5	29.3	1.8	3.4	0.72	0.09	35.3	44.1	17	
	Cg	90-125+	14	46	40	4.4	0.3	11.0	2.2	2.8	0.56	0.12	16.7	41.7	34	

1/ See Table 5.

Table 7. Characteristics of two Spodosols from coarse textured parent materials in the Upper Amazon Basin.

Profile No.	Horizon		Sand	Silt	Clay	pH	O.M.	Exchangeable Al	Ca	Mg	K	Na	CEC (sum)	Base Satn
		cm	%	%	%		%	meq/100g						%
Y-8	A1	0- 19	90	6	4	4.6	2.1	0.25	2.2	0.2	0.20	0.04	2.85	91
	A21	19-115	86	12	2	4.6	0.3	0.10	0.4	0.1	0.16	0.04	0.80	88
	A22	115-150	85	12	2	4.6	0.3	0.15	0.2	0.1	0.14	0.04	0.63	76
	A23	150-180	92	8	0	4.1	0.3	0.20	0.2	0.1	0.12	0.02	0.64	23
	Bhirm	180-210	74	10	16	4.5	3.7	1.50	0.2	0.1	0.12	0.02	1.94	67
1-5	A1	0- 15	88	10	2	4.2	4.9	0.15	2.6	0.2	0.12	0.04	3.11	95
	A2	15- 50	84	14	2	5.1	0.5	0.10	0.6	0.1	0.08	0.02	0.92	89
	Bh	50- 66	84	14	2	5.1	1.3	0.10	1.2	0.1	0.06	0.04	1.50	93
	IIA12	66- 75	84	14	2	5.1	1.0	0.05	0.6	0 1	0.08	0.04	0.87	94
	B2	75-100	86	12	2	5.1	1.3	0.10	0.4	0.1	0.06	0.04	0.70	86
	B3	110-150	86	12	2	5.2	1.1	0.00	0.2	0.1	0.04	0.04	0.38	100
	C1	150-190+	84	14	2	5.2	0.6	0.00	0.4	0.1	0.04	0.04	0.22	100

Ultisols cover the largest proportion of the areas studied. Morphologically, these soils are very similar to many soils of the Upper Coastal Plain and Piedmont areas of North Carolina and other Southeastern States. This permits a direct extrapolation of basic concepts of soil genesis and morphology, which have to be adapted to an entirely different climatic and agricultural situation. Many of these soils contain considerable amounts of weatherable minerals (except for the siliceous families) and are probably not as infertile as previously thought. It is our contention that the more weathered Oxisols predominate in the geologically older landscapes of the Guyana and Brazilian Shields, but that in the more recent Amazon Basin deposits their occurrence is limited.

Within the Yurimaguas station, a detailed soils map is in the process of being prepared by Mr E. J. Tyler to locate the management experiments in soils that will permit a maximum degree of extrapolation of the results to the region.

Soil Management Studies

A 2-hectare tract of a 17-year old virgin forest, located on a Typic Peleudult soil was cleared in August of 1972 by Mr. C. E. Seubert and Peruvian counterparts. The conventional slash and burn clearing system was compared to clearing with a bulldozer without burning. Several cropping sequences were planted including crops of upland rice, pastures and grain sorghum. Through periodic soil and plant analysis, the changes that the soil undergoes in the fertility depletion process are being studied. The most significant effect so far is the dramatic differences in water infiltration rates between the two land clearing processes (Table 8). The lower infiltration rates with the bulldozer clearing are associated with soil compaction caused by the machine and the removal of part of the topsoil by the bulldozer blade.

Table 8. Water infiltration rates as affected by land clearing methods in Yurimaguas. (Typic Paleudult soil)

Land Clearing System	After Clearing and Burning	Three Months After Clearing & Burning
	cm/hr	
Conventional slash and burn	14.1	5.1
Bulldozer clearing	0.4	1.8
Secondary forest	-	26.1

Table 8 also indicates that the difference between the two systems tends to decrease with time and that in both land clearing systems infiltration was lower than that of an uncut secondary forest. These differences have been accompanied by sharp differences in the growth of rice, guinea grass and green sorghum. The growth of these crops is superior in the slash and burn plots than in the bulldozed areas. Several nutrient deficiency symptoms have appeared in the bulldozed areas. Until the analytical data are available, no major conclusions can be drawn. Nevertheless, there is no doubt about the initially beneficial effect of the conventional slash and burn practice.

RESEARCH IN THE CAMPO CERRADO OF BRAZIL

Objectives and Organization

About 43 percent of the potential arable and grazing land in the tropics consists of savannas and other grasslands. The largest such area is the Campo Cerrado of Brazil with 183 million hectares or approximately 20 percent of Brazil's land surface. Parts of the Cerrado are being rapidly populated with cities like Brasilia and Gôiania of about half a million people each. The gentle topography makes it quite attractive for extensive mechanized agriculture. Where the roads have reached, probably the main limiting factor is the low native fertility and low available water range of the Oxisols.

In 1971, the Brazilian Ministry of Agriculture and the USAID Mission requested Cornell and North Carolina State University to conduct research related to the efficient use of fertilizers and available water in the Cerrado. An agreement was signed during last year for a joint NCSU-Cornell Project to be headquartered at the Estação Experimental de Brasília.

Drs. E. J. Kamprath, S. W. Buol and F. R. Cox made several study trips to the area to gather background information to help in the design of field work. Some of their suggestions were implemented by a Peace Corps volunteer assigned to the Brasília Station. This report describes the preliminary activities.

The field portion of the work started in October of 1972 with the arrival of Dr. George Naderman from Cornell and Ing. Enrique Gonzales E. of NCSU. Mr. Russell S. Yost of NCSU and Mr. James M Wolf of Cornell are scheduled to join the team in early 1973.

In late 1972 the team installed experiments on nitrogen, phosphorus, depth of liming, zinc rates and zinc-lime interaction, the latter in cooperation of Dr. F. R. Cox. Also a small laboratory was set up at the Station to conduct key chemical analysis. Excellent cooperation has been provided by Wilson Soares, the Station Director, Dr. R. B Cate of ISFEI, the Ministry, and USAID Mission personnel.

Field Moisture Study

Many reports question the validity of field capacity approximations through laboratory procedures in Oxisols. In order to test such validity Dr. Buol designed a series of simple experiments which were conducted by Mr. David Olson of the Peace Corps. The results in Table 9 show the actual field moisture capacity of these soils. These figures are somewhat higher than 1/3 bar determinations.

Table 9. Actual moisture contents at field capacity (determined in the field) of four Oxisols of the Brasilia Experiment Station.

Soil	% H_2O at field capacity	
	0-20 cm	20-40 cm
Dark Red Latosol (Acrustox) Virgin	27.7	26.6
Dark Red Latosol (Acrustox) cultivated	25.6	25 4
Red Yellow Latosol (Acrustox)	28 0	31 9
Low Humic Gley (Aquox)	24.5	27.0

Phosphorus and Lime studies

Phosphorus deficiency is one of the main factors limiting growth on the Campo Cerrado Oxisols in Brazil. Because of the high phosphorus fixation capacity of these soils resulting from the high iron oxide content, relatively large amounts of fertilizer phosphorus have to be added for optimum plant growth Laboratory studies were conducted to determine the amount of fertilizer phosphorus which has to be added to provide a concentration of 0.05 ppm of P in the soil solution, a level which has been suggested as adequate for optimum growth.

The amounts of fertilizer P required to give a soil solution concentration of 0.05 ppm of P was 1166 kg P/ha for the soil which had been limed in 1967 and 797 kg P/ha for the soil to which sodium silicate had been added (Table 10). The fertilizer P required to give an adequate soil solution level of P was markedly reduced when sodium silicate was applied.

The silicate ion reacts with hydrated oxides of Fe and Al in a similar manner as phosphate and in this way reduces the phosphorus fixation capacity. Calcium silicate is a byproduct of cement production and can be used as a liming material. Where soils have high phosphorus fixation capacities and are acid the use of calcium silicates as a liming material may be preferable to calcium carbonate because of its additional benefit of reducing phosphorus fixation.

Table 10. Amount of fertilizer phosphorus which has to be added to a Dark Red Latosol (Acrustox) to give a soil solution level of 0.05 ppm of P.

Treatment	Soil pH	Fertilizer P Requirement kg P/ha
Unlimed	4.5	1166
Limed	5.5	1056
Na silicate	-	797

High exchangeable aluminum sat[illegible] of acid subsoils limits root growth and utilization of subsoil moisture. One of the probl[illegible] producing high crop yields on such soils is how to increase the calcium content of the subsoils. The exchangeable calcium content of the subsoils were appreciably higher four years after the topsoil was limed as compared with the unlimed soil (Table 11). The exchangeable aluminum content and saturation were also reduced. Movement of calcium from limed surface soils is suggested by these data. It may result in some improvement of the chemical environment of the subsoil and promote deeper root development.

Table 11. Calcium and aluminum contents of the subsoil (20-40) of a Red Latosol as influenced by liming of the surface soil at Brasilia.

Sample	Treatment of surface soil	Exch. Ca (meq/100 g.)	Exch. Al (meq/100 g.)	% Al Saturation
1	Unlimed	0.11	1.78	92
	Limed	0.54	1.38	70
2	Unlimed	0.06	2.65	96
	Limed	0.54	1.56	76

DISSEMINATION OF RESULTS

The effectiveness of a research contract such as this should be measured by the generation of information not previously available to workers in the developing countries. Emphasis has been given to publishing and distributing the findings of the review phase of this program as quickly and thoroughly as possible. Additional publications were written on contract time for more specific aspects and published separately. A mailing list with about 350 soil scientists and institutions throughout the world was assembled and used for distributing this information. In addition, 100 copies are sent to AID for their own distribution. Judging from the responses the impact of this new information has been substantial in Latin America and the tropics as a whole.

The following papers were published with total or partial contract support during the year. Several of the English versions are in the process of being translated into Spanish.

1. Bartholomew, W. V. 1972. Soil nitrogen and organic matter, pp 63-81. Committee on Tropical Soils: Soils of the Humid Tropics. National Academy of Sciences, Washington, D.C.

2. Benavides, S. T. 1972. Mineralogical and chemical characteristics of some soils of the Amazonia of Colombia. Ph.D. Thesis, North Carolina State University, Raleigh. 216 pp.

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In addition, staff members have presented papers based on contract work at the following conferences or seminars:

1. Second Soils Colloquium of the Colombian Society of Soil Science, Palmira, Colombia, August 1971. (Drs. McCants and Sanchez).

2. Annual Agronomy Meeting of the National Rice Program in Lambayeque, Peru, October 1971. (Dr. Sanchez).

3. Seminar of Rice Policies in Latin America, Centro Internacional de Agricultura Tropical, Cali, Colombia. (Dr. Sanchez).

4. Symposium on Liming in the Tropics. Soil and Crop Science Society of Florida, Gainesville. December 1971. (Dr. Kamprath).

5. Lectures at Cornell University. March 1972. (Dr. Sanchez).

6. Tropical Soils Research Seminar, International Institute for Tropical Agriculture, Ibadan, Nigeria. May 1972. (Dr. Buol and Dr. Sanchez).

7. Fourth Annual Meeting of the Advisory Committee on Rice Fertilization, Tennessee Valley Authority, Bangkok, Thailand. May 1972. (Dr. Sanchez).

8. Tropical Soils Institute, Mayagüez, Puerto Rico, sponsored by the 211(d) Consortium. July-August 1972. (Drs. Buol, Kamprath, Sanchez).

9. Tropical Soils Workshop, Prairie View A & M College, Texas. October 1972. (Dr. Sanchez).

10. Symposium on Soil Fertility in Latin America, American Society of Agronomy Annual Meeting, Miami, Florida. (Drs. Benavides, Sanchez, Kamprath, Oelsligle) November 1972.

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