AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

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Batch #26

1. SUBJECT CLASSIFICATION

A. PRIMARY
Serials

Y-AF20-0000-GG50

B. SECONDARY
Agriculture--Soil science--Tropics

2. TITLE AND SUBTITLE
Agronomic-economic research on tropical soils; annual administrative report,Jan.-Dec. 1974

3. AUTHOR(S)
(101) N.C.State Univ. Soil Science Dept.

4. DOCUMENT DATE
1975

5. NUMBER OF PAGES
39p.

6. ARC NUMBER
ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
N.C.State

8. SUPPLEMENTARY NOTES *(Sponsoring Organization, Publishers, Availability)*
(Adm.and activity summary)

9. ABSTRACT

10. CONTROL NUMBER
PN-RAB-512

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Tropics

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-2806 Res.

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

AGRONOMIC-ECONOMIC RESEARCH ON TROPICAL SOILS

CONTRACT AID/csd 2806

Annual Administrative Report

for the period

January 1 to December 31, 1974

Soil Science Department

North Carolina State University

REPORT SUMMARY

A. Statistical Summary

1. Project Title Contract Number: Agronomic-Economic Research on Tropical Soils. AID/csd 2806.

2. Principal Investigator, Contractor and Mailing Address: P. A. Sanchez, Soil Science Department, North Carolina State University, Raleigh, N. C. 27607.

3. Contract Period: June 30, 1970 to June 30, 1975.

4. Period covered by Report: January 1 to December 31, 1974.

5. Total AID funding to date: (June 30, 1970 to March 31, 1975): $1,128,360.

6. Total expenditures and estimated obligations through previous report period: (Dec. 31, 1973): $632,335.

7. Total expenditures and estimated obligations for current year: (1/1/74-12/31/74): $396,025.

8. Estimated expenditures for remainder of contract period: (June 30, (June 30, 1976): $197,978.

B. Narrative Summary of Accomplishments and Utilization

Research in the Amazon jungle showed that the decline in soil fertility after land clearing is very fast in acid Ultisols. The slash-and-burn land clearing methods slows the rate of decline as compared to land clearing with a bulldozer. The slash and burn method also produces higher crop yields and more profits to small farmers than the mechanized clearing. Continuous cropping in this area seems feasible with moderate fertilizer and lime inputs. The most promising cropping system in an annual rotation of upland rice, corn and soybeans. Several practices aimed at developing low energy technology appear promising: 1) The use of *Stylosanthes guyanensis*, an acid tolerant legume in pastures produced annual dry matter equivalent to 100 kg N/ha as urea, 2) the use of Fosbayovar rock phosphate from the Peruvian coast is promising alternative to superphosphates, 3) a multiple cropping system produced four crop harvests in nine months and, 4) the use of mulches and incorporation of Kudzu has increased crop production effectively.

Research in an Oxisol savannas demonstrated the superiority of deep vs. shallow depths of lime incorporation in three consecutive corn crops. Residual effect studies show that an initial broadcast application of 80 to 320 kg P_2O_5/ha followed by banded applications of 80 kg P_2O_5/ha per crop produced about 70 to 85% of the maximum yields attained by heavy broadcast applications. Several cheaper phosphorus sources seem promising. Crop yields are closely related to the frequency and intensity of short-term droughts during the rainy season. Varietal differences in tolerating high levels of exchangeable aluminum and low levels of available soil phosphorus were identified. The potential for irrigation and water impoundment was also determined.

Research on intensive multiple cropping systems in Costa Rica showed the superiority of intercropped systems as opposed to monocultures of several fertility levels. Characterizations studies in various parts of Latin America were conducted to assess the possibilities of extrapolating data. All project publications were quickly distributed.

C. Project Objectives

This program 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 soil management information to increase food production in tropical soils and improve the well being of small farmers.

The program consists of two phases. The objectives of phase one are to review, analyze and interpret published literature and other sources of information related to soil factors influencing crop production in tropical regions and to identify major problems and sites for in-depth research in second phase. Phase I was essentially completed by 1973. Phase II consisted of generating additional agronomic and economic data consistent with the objectives. Based on the results of Phase I, three major ecological regions were selected for field studies, based on the need to obtain further soils related information and the potential for increasing food production in them. They are: 1) the tropical jungles which account for 30% of the tropical land mass, 2) the acid tropical savannas which account for an additional 31% and, 3) the highly populated highlands affected by volcanic ash. After on-site studies and agreement with local institutions, field experiments were initiated in August 1972 in the following representative locations: Yurimaguas, Peru for the jungle, Brasilia, Brazil for the savannas and the Central America Highlands with headquarters in Turrialba, Costa Rica.

D. Accomplishments to Date

1. Findings

1.1 Compilation of the literature on soils research in Tropical Latin America, analysis of priorities, and publication in English and Spanish.

1.2 Development of a fertility-capability soil classification system aimed at a more direct and rational means for grouping together soils with similar fertility limitations. Such a system will permit a more meaningful extrapolation of data from field experiments to other areas with similar soils.

1.3 Agronomic and economic evaluation of the above system. Results from 73 field experiments on potato fertilization in the Sierra of Peru confirm that soils belonging to the same fertility-capability grouping behave similarly in terms of fertilizer response. When soils were grouped in this fashion the fertilizer recommendations increased the net profit by $150/ha. When both the fertility-capability groupings and soil test values were used the net profit increased to $195/ha.

The analysis of a data set from Brazil affords an assessment of the potential of Fertility-Capability Classification System as a means for grouping soils with fertility management problems. The parameters for the type and substrata type categories appear to adequately define soils into broad but distinct classes that will warrant separate fertilizer management practices. The condition modifiers for low cation exchange capacity and aluminum toxicity were useful in separating different yield responses. The "k" and "i" modifiers need redefinition in order to improve their ability to group soils with similar problems of potassium deficiency and phosphorus fixation by iron.

1.4 Characterization studies of Amazon Jungle soils indicate that Ultisols rather than Oxisols are the predominant well drained soils of the Amazon Basin outside of the influence of the Guyana and Brazilian shields. These soils have management characteristics quite different from the Oxisols. Studies in the Colombian Amazon have been completed; a detailed

soil map of the Yurimaguas station is expected to be completed next year.

1.5 Research in Yurimaguas showed that the fertility decline after land clearing is very fast for these acid Ultisols. The slash and burn land clearing method however, slows the rate of fertility decline as compared with land clearing with a bulldozer. After burning, total exchangeable bases and available phosphorus increased several fold. This reduced aluminum saturation to nearly acceptable levels. The pattern of organic matter depletion was retarded by six months with the traditional slash and burn system. Crop performance during two years showed that the average yields in bulldozed plots were 1/3 of those of the burned plots when no fertilizer was added, and that this difference gradually decreased with fertilization intensity. The economic analysis shows that mechanized land clearing is unprofitable while the traditional slash and burn system was profitable at the small farm level.

1.6 Continuous cropping is agronimically and economically feasible with relatively modest fertilizer and lime inputs. After correcting the soil pH to 6.0 and adding a basal application of 100 kg P/ha plus sulfur, boron and molybdenum, crop yields were maintained at a satisfactory level with 40 to 80 kg/ha of nitrogen and potassium additions per crop. The most promising cropping system appears to be a three-crop yearly rotation of rice, corn and soybeans which produced average grain yields between 2.5 and 3.5 ton/ha per crop. These systems are profitable with the new fertilizer subsidy prices recently put into effect in Peru.

1.7 Pasture fertilization experiments show that the establishment of *Stylosanthes guyanensis* produces as much annual dry matter of Guinea grass

(*Panicum maximum*) as 100 kg N/ha/yr as urea. Maximum yields were attained with 400 kg N/ha/yr as urea but the same yields were obtained with 100 kg N/ha/yr of sulfur-coated urea, a slow release nitrogen source. The phosphorus requirements are lower than commonly assumed due to the low phosphorus fixation capacity of this soil. The Fosbayovar rock phosphate produced in the coast performed well when compared with the international rock phosphate standards. This low-cost source seems to offer real promise for Jungle Ultisols.

1.8 Multiple cropping experiments show that four crops (corn, soybeans, cassava and cowpea) can be produced in nine months and that the gross returns per hectare are considerably higher than that of monocultures. The response to both nitrogen and lime is higher in intercropped combinations than in monocultures. Incorporating Kudzu (*Pueraria phaseoloides*) tops increased drastically soybean yields and nodulation. This practice may reduce fertilizer costs and make good use of cheap, locally available material.

1.9 A preliminary model was developed for continuous cropping based on low-energy technology for small farms or cooperatives. Some of its components will require further testing.

1.10 The management of savanna Oxisols is a matter of fertility-subsoil moisture interactions and not fertility alone as previously thought. Liming to pH 5.5 at 30 cm depth increased corn yields and decreased soil moisture stress during droughts periods which take place during the rainy season. Only a moderate rate of 2 tons of lime per hectare when incorporated at 30 cms was necessary to produce high yields in the first two crops.

1.11 Although applications of nitrogen, potassium and zinc are also necessary in these soils, the amounts required are also within the economic range. Phosphorus is undoubtedly the main limiting fertility factor. These Oxisols can fix about 2650 kg P_2O_5/ha Broadcast rates of up to 320 kg P_2O_5/ha were sufficient to obtain maximum yields in the first rainy season crop. The dry season crop indicated a substantial residual effect of broadcast rates of 640 kg P_2O_5/ha or higher. The high cost of these applications using single superphosphate raises serious economic questions. Lower cost fertilizers such as rock phosphates or silicate applications are presently being evaluated in new trials. These experiments are long-term ones.

1.12 The cooperative research project in Brasilia produced the first indication of the residual effects of lime, phosphorus and zinc applications in 1974. The superiority of deep lime incorporation has remained consistent in three consecutive corn crops. The ability of corn roots to extract nutrients and moisture at greater depths in extremely acid subsoils is considered the main reason for the superior performance of deep lime incorporations. After three consecutive crops, the residual effect of 4 and 8 tons lime/ha is strong and is confirmed by profile chemical analysis.

1.13 The comparison of broadcast vs. banded superphosphate applications on four consecutive corn crops shows a different residual effect with time. Broadcast applications of 160 and 320 kg P_2O_5/ha failed to maintain adequate yield levels, while the very high level of 1280 kg P_2O_5/ha consistently produced the highest yield. Banded applications prior to each crop gradually increased their effectiveness. A tentative economic analysis of the first four crops show that the most profitable strategy is

to apply a relatively large initial broadcast application of 320 kg P_2O_5/ha plus a banded application of 80 kg P_2O_5/ha before each crop. The present cost:price ratios in Brazil make these considerable investments in fertilizers profitable.

1.14 In search for cheaper sources of phosphorus, experiments with forage species show that the Termosfosfato (a thermal alteration of slowly soluble Araxá rock phosphate with magnesium silicate) produced initial satisfactory forage crop responses similar to that of superphosphate. In addition this source had a considerable liming effect on the soil. The residual effects are being investigated. The residual effects of the 3 kg Zn/ha applications were strong for the second crop.

1.15 The two year study of soil moisture properties with emphasis on dry spells ("veranicos") which occur during the rainy season was completed during this year. Analysis of long term rainfall records indicate that the probability of severe water stress for corn is high in most years. The available water storage capacity of the loamy-textured Oxisol was found to be 30 percent higher than a clayey textured Oxisol. The difference is attributed to the extremely strong aggregation of clay particles into sand-sized granules. Crop yields showed good agreement with the length of "veranicos." Probability analysis shows that long term rainy season corn yields will average 54 percent of the maximum yields due to "veranicos." The potential for irrigation and water impoundment was also determined.

1.16 Studies on varietal differences in tolerating high levels of aluminum and low levels of phosphorus were initiated. Culture solution studies show that these factors are interrelated and that significant differences exist among corn, rice and bean varieties. Field studies will follow.

1.17 The first extrapolation study to other Cerrado soils were conducted this year. Work on the loamy Red-Yellow Latosol showed no response to depth of lime incorporation because subsoil aluminum saturation was below critical levels in the soil. A second experiment with beans underscored the importance of banding phosphorus for this crop. The study of a large number of topsoil samples throughout the Cerrado showed the very uniform low fertility parameters in the area. The natural vegetation gradient from campo limpo (pure grassland) to deciduous forest through several intermediate steps was found to be directly associated with increasing soil pH, exchangeable calcium, magnesium, potassium, effective cation exchange capacity and available phosphorus, zinc and magnesium.

1.18 In the highly populated Central American region, deficiencies of sulfur and zinc were found in several crops grown in the Guatemala Altiplano and Pacific Coast. Extremely serious droughts during the past rainy season prevented the verification of S and Zn responses in field experiments. The new ICTA-ISFEIP field soil fertility program is presently using this information in a large number of field experiments.

1.19 Research on intensive multiple cropping systems in Costa Rica showed the superiority of intercropped systems as compared with monocultures at several fertility levels. A four crop combination of corn, bush beans, cassava and soybeans harvested in one year with a total fertilization of 212-144-132 kg N, P_2O_5/ha on a Dystrandept produced maximum returns over fertilizer costs and a very high total edible energy and protein production. Nitrogen response was higher when corn and beans were intercropped than when the field was split in halves and planted with two monocultures.

1.20 New sources of nitrogen and phosphorus are being studied for upland rice. Economic interpretation of upland rice response to different nitrogen management alternatives show a wide variety of profitable alternatives and the that more profit was made with the higher 1974 prices, when the cost of nitrogen tripled and the price of rice increased by 84 percent.

1.21 The nitrogen requirements to maximize forage sorghum production during the rainy season are being studied in five locations in Northern El Salvador. The purpose of this study is to provide sufficient feed for cattle during the dry season using simple trench silos. Initial studies are also underway aimed at eliminating copper-toxicity to rice and other crops in lands formerly operated by banana plantations.

1.22 Soil characterization studies have been conducted to obtain basic data needed for extrapolation studies. The map of the Yurimaguas Experiment Station was also completed during the year. Local variability of Ultisols, Alfisols, Inceptisols and Entisols is largely explained in terms of geomorphic surfaces. Variation in properties of the upland soils are directly related to clay content. Geomorphic relationships also explain local variability in a selected landscape in western São Paulo, Brazil. Oxisols, Ultisols, Alfisols and Mollisols occupy predictable positions in the landscape. Characterization studies were also made in the Llanos Orientales of Colombia, the Maracaibo basin of Venezuela and in the lowlands of that country. The slow mineralization rate of Andepts of Colombia is attributed to the low available phosphorus and nitrogen content of such soils.

1.23 Economic analysis of fertilizer response data gathered by other institutions indicates that the Waugh-Cate-Nelson, Linear Response and

Plateau Model is as effective as the more complicated generalized quadratic equations. Economic studies have also established the profitability of soil test recommendations in Brazil and Costa Rica.

2. Operational Significance

The need for increasing world food production and improving the quality of life of the poor farmers has been recognized by AID and other donors as a major one. The fact that the greatest potential for increasing world food production lie in vast underdeveloped regions in the tropics is also well recognized. The fact that man's knowledge on how to fertilize and manage such tropical soils is very limited is also well recognized throughout the world. Direct adaptation of the basic principles of soil science developed in non-glaciated temperate regions to tropical soils is possible. Direct adaptation of soil fertility and management practices developed in the temperate regions is seldom possible because of the drastically different climatic economic and social constraints. Improvement in soil management practices for these regions must draw both from the basic principles of soil science (for example, the chemistry of exchangeable aluminum) and from an understanding of the traditional tropical soil management systems per se. Due to the high costs of outside inputs such as fertilizers, lime, pesticides and in many cases from machinery, and due to the high risks associated with such investments, the strategy for increasing soil production should be aimed at determining low-risk economic levels of inputs rather than the levels needed for maximum yields.

The recent successes of the "green revolution" programs are limited to the small minority of the tropics with soils of high native fertility and often available irrigation. Before the impact of the new improved

varieties can be felt on these vast tropical areas, much more knowledge of how to manage these basically infertile, unirrigated humid tropical soils is needed.

The three tropical regions on which this research contract focuses cover a large proportion of the tropics. Tropical rainforests cover approximately 30% of the tropical land mass. The largest areas are in the Amazon and Congo Basins and in the hill country of Southeast Asia. A large proportion of the tropical rainforests have similar soil properties and rainfall regime to that found in the Yurimaguas Station. Tropical savannas with acid soils such as those of Brasilia cover approximately 31 percent of the tropical land mass. The largest areas are in the Cerrado and Llanos of South America as well as in central and eastern Africa surrounding the Congo Basin. The areal extent of subsistence intercropping tillage in volcanic areas is difficult to estimate. It is probably less than 5% of the tropics, but the numbers of people involved is substantially larger. In addition to the Central American highlands, similar conditions exist in parts of Indonesia and the Philippines and in the Rift Valley of Africa.

Although research on shifting cultivation has been conducted for many years in Africa, particularly by Belgian, French and British scientists in colonial days, no specific recommendations on how to transform these systems into continuous cropping when population pressures increase have been developed When this question was asked of African scientists at a meeting on Tropical Soils Research in Ibadan, Nigeria in 1972, none present could say that they had a set of packages which they could recommend to solve this problem. Since 1971, IITA's Farming Systems Program has been attacking this problem in a systematic fashion in

seasonal forested areas with high base status Alfisols. To our knowledge, the only other ongoing systematic soils research program on shifting cultivation is this Yurimaguas project. It is also the only one working on acid soils and the only one in the Amazon basin. Its results so far have captured the attention of soil scientists and development officials of the Amazon countries. Cooperation with IITA has served to sharpen the operational objectives of both institutions.

The management of acid savanna Oxisols is primarily a matter of determining economic application rates of phosphorus, lime, other nutrients and their interactions with moisture stress. A large body of research information has accumulated particularly in the southern part of the Brazilian Cerrado, the Llanos Orientales of Colombia and parts of Africa. Most of the African research on tropical savannas related to high base status soils, particularly in West Africa and Kenya. Most of the knowledge gathered in those savannas is limited to short-term experiments with perhaps one or two harvests. Such data is unsuitable for determining the residual effects of lime, phosphorus and micronutrient applications required for an adequate economic interpretation. The long-term nature of the experiments in Brasilia is the most significant aspect of this project.

Very little is presently known on how to manage soils and fertilizer applications in intercropped systems. This is undoubtedly one of our greatest gaps in tropical soil science. Attention to this subject was sparked by Bradfield's work on multiple cropping in IRRI. His results, however are limited to systems which involve growing flooded rice during the rainy season. Ongoing work at IRRI under the direction of Richard Harwood, at Turrialba by our staff and CATIE, in Yurimaguas and in

Northern Nigeria is beginning to provide good leads. Our accomplishments although limited, are helping to develop a better research methodology on how to improve soil fertility under multiple cropping systems.

Considerable progress has been made in the art of developing a sound methodology for interpreting and extrapolating soil fertility and management research results to other areas. The methods developed by the International Soil Fertility Evaluation and Improvement Program (Cate-Nelson graphs, Linear Plateau and Response Model) offer simplified procedures for making fertilizer recommendations based on field data. Such techniques do not require complicated economic and statistical analysis, and recommendations can be obtained without the use of computer. An economic evaluation of these techniques in comparison with the classic quadratic equations, conducted as part of this research contract, has as yet shown no substantial differences in profitability between the two methodologies.

Prior to the initiation of this contract, no systematic procedures were available to extrapolate field fertility data from one region to the other. Natural soil classification systems, including the new U.S. Soil Taxonomy, does not provide for such groupings because they focus on subsoil parameters and essentially ignore the plowed layer where most of the fertility interactions take place. The Fertility Capability Classification System, developed under this contract, is being designed to group soils with common fertility-management problems. It weights topsoil properties more heavily without ignoring important subsoil parameters. Its initial evaluation shows substantial promise but also the need for some modification of the original scheme. In the extrapolation process additional soil characteristic data is needed, as well as certain

laboratory and greenhouse procedures. Considerable progress has been made in characterizing soils in our areas of emphasis, but more work is needed particularly when extrapolation-type field research requests come in from the LDC's.

3. Side Effects of the Work

The program has developed insights beyond the original scope of the work on how to manage soils under shifting cultivation, acid Oxisol savannas and in the methodology for extrapolation. These are discussed in detail in the 1973 and 1974 technical annual reports. No unexpected complications beyond those common of international work have been encountered.

4. Research Design

No significant modifications have been made in this aspect. The present design focusing on three major ecological regions, conducting several long-term in-depth experiments in cooperation with national institutions and providing the necessary backstopping from Campus remains very effective. At the experimental design level no major problems have arisen.

E. Dissemination and Utilization of Research Results

1. Project Output

In order for the data to reach its intended audience (soil scientists and administrators concerned with LDC's) as quickly as possible, a mechanism other than formal research publications in scientific journals was needed. Formal research articles are normally published from 2 to 4 years after the data is gathered. In order to accelerate the process, an annual technical report is published with comprehensive data and its interpretation. Portions of these reports are translated into Spanish or Portuguese.

a) Reports, Scientific Articles and Theses

Alvarado, A. 1974. A volcanic ash soil toposequence in Costa Rica, Central America. M.S. Thesis, Soil Science Department, North Carolina State Univ. 89 pp.

Batavia, B. N. 1974. Specific errors and empirical estimation of generalized crop-fertilizer response functions. Ph.D. Thesis, Economics Department, North Carolina State Univ. 106 pp.

Lepsch, I. F. and S. W. Buol. 1974. Investigations in an Oxisol-Ultisol toposequence in São Paulo State, Brazil, Soil Sci. Soc. Amer. Proc. 38(3):491-496.

Munévar, F. 1974. Some factors affecting the mineralization of organic matter in volcanic ash soils. M.S. Thesis, Soil Science Department, North Carolina State Univ. 101 pp.

North Carolina State University. 1974. Research on tropical soils. Annual Report for 1973. Contract AID/csd 2806. 190 pp.

North Carolina State University. 197 Proyecto internacional de suelos tropicales-Yurimaguas, Peru. Informe anual 1972-73. Ministerio de Agricultura, Yurimaguas, Peru. 46 pp.

Sanchez, P. A., C. E. Seubert, E. J. Tyler, C. Valverde, C. E. Lopez, M. A. Nureña, and M. K. Wade. 1974. Investigaciones en manejo de suelos tropicales en Yurimaguas, Selva Baja del Perú. pp II-B-1-II-B-37. En: IICA: Reunión Internacional sobre sistemas de Producción para el Tropico Americano (Sistemas de Uso de la Tierra). Instituto Interamericano de Ciencias Agrícolas, Lima, Perú.

Sanchez, P. A., and S. W. Buol. 1974. Properties of some soils of the Upper Amazon Basin of Peru. Soil Sci. Soc. Amer. Proc. 38:117-121.

b) Manuscripts accepted for publication

Buol, S. W., P. A. Sanchez, R. B. Cate, Jr., and M. A. Granger. Soil Fertility-Capability Classification: A technical classification for fertility management. Seminar on Soil Management and the Development Process in Tropical America, CIAT, Cali, Colombia (In English and Spanish), Mimeographed, 24 pp.

Oelsligle, D. D. Accumulation of dry matter, nitrogen, phosphorus and potassium in cassava (*Manihot esculenta* Crantz). To be published in Turrialba.

Salinas, J. G. and P. A. Sanchez. Soil-plant relationships affecting varietal and species tolerance to low available soil phosphorus. Accepted for publication in "Ciência e Cultura." (In English and Portuguese). Mimeographed, 36 pp.

2. Dissemination

Mailing list

All publications continued to be sent free of charge to whoever requests to have his name included in the mailing list. At the time of writing a total of 491 individuals and institutions were receiving this service. Of these 251 are from Latin America, 103 from the United States, 29 from Asia, 27 from Africa, 21 from Europe and 60 on campus. Most of the individuals in this list are soil scientists and administrators of institutions working on international agricultural development.

3. Utilization

a) Participation in Conferences and Symposia

Staff members of the project have been invited to present the research results at several scientific and policy making conferences

in the LDC and the United States. A short description of these activities follow.

Feb. 14-20, Cali, Colombia: Seminar on Soil Management and the Development Process in Tropical America. Several members of this research contract and colleagues from cooperating institutions participated in this regional seminar organized by the University Consortium on Soils of the Tropics, AID, CIAT, the Colombian and the Latin American Societies of Soil Science. These included Drs. McCants, Sanchez, Oelsligle, Naderman, Wolf and Granger. Three papers based on this research program results were presented. They dealt with the fertility-capability classification system, soil moisture studies in Brazil and liming of soils associated with Brazilian Cerrado.

The post-Seminar tour carried an average of 40 leading soil scientists from different countries of Latin America, Asia, Africa, Europe and the United States to the Yurimaguas and Brasilia experiment stations. The ongoing work was presented by Dr. Sanchez, Ing. Nureña, Messrs. C. E. Lopez and M. K. Wade in Yurimaguas and by Drs. G. C. Naderman, W. Goedert, Messrs. W. V. Soares, M. N. Camargo, J. M. Wolf, E. Gonzalez and R. S. Yost in Brasilia. This provided an opportunity for these scientists to have first hand contact with our experimental objectives and results.

Feb. 25-27, Turrialba, Costa Rica: Conferencia sobre Sistemas de Producción Agrícola para el Trópico (Conference on Tropical Agricultural Production Systems). This conference organized by our host institution CATIE, had the objective of discussing the formation of a Central American cropping systems research program. Dr. Sanchez

chaired the section of agronomic aspects and drafted the recommendations on this subject. Dr. Oelsligle presented some of his field results and actively participated in the discussions. The eventual outcome of this conference was the awarding of the Cropping Systems Research Contract to CATIE by AID/ROCAP.

June 10-15, Lima, Perú: Reunión Internacional sobre Sistemas de Producción para el Trópico Americano (International Meeting on Production Systems for the American Tropics). This IICA-sponsored meeting brought together an interdisciplinary team of scientists and development officials from the six Amazon countries (Bolivia, Brazil, Colombia, Ecuador, Peru and Venezuela) to discuss the development of the region. The results of the Yurimaguas project were presented for the first time to an audience of scientists and policy makers from the Amazon Jungle region by Dr. Sanchez.

July 10-17, Recife, Brazil: Simpósio sobre Melhoramento de Plantas para Resistença a Condições Noçivos de Alumínio e Manganés no Solo (Symposium on Breeding for Varietal Tolerances to Toxic Soil Aluminum and Manganese). Two papers were presented by the project staff at this symposium which was co-sponsored by the Brazilian Genetics Society and the Brazilian Association for the Advancement of Science. Dr. Naderman presented the results of the liming and moisture studies, and Dr. Sanchez presented the review of soil-plant relations affecting tolerances to low soil phosphorus availability.

July 17-18, Campina Grande, Paraíba, Brazil: Intensive Short Course on Research with Meteorological Data and utilization of Water Resources. Dr. Naderman gave two 90-minute presentations of the principal concepts and methodology involved in the fertility-moisture

research orientation of the Brasilia project in Portuguese to 25 participants of this short course sponsored by EMBRAPA, Utah State University and other institutions concerned with the development of northeast Brazil.

July 22-24, Lima, Peru: Primer Congreso Nacional de la Ciencia del Suelo (First National Soil Science Congress). Dr. Sanchez was one of the keynote speakers in this meeting with the topic "Management of Tropical Soils." The Spanish version of the 1973 Annual Report of the Amazon Jungle was distributed. Mr. C. E. Lopez was co-chairman of the Jungle soils section.

Sept. 18 and 25, Brasília, Brazil: Conceitos Críticos sobre Fertilidade e Agua para Agricultura en Areas do Cerrado (Critical concepts regarding fertility and water for agriculture in Cerrado areas). This consisted of two lectures in Portuguese by Dr. Naderman to an Agronomy class at University of Brasilia.

Oct. 21. Brasilia, Brazil: Pesquisa sobre Solo e Nutrição de Plantas para Agricultura no Cerrado (Research on soils and plant nutrition for agriculture in the Cerrado). This lecture was given in Portuguese by Dr. Naderman, This was one of ten presentations in a series of conferences on recent developments in crop and soil technology sponsored by the University of Brasilia. About 1000 persons attended including agricultural specialists University staff and students.

November 10-15, Chicago, Illinois: American Society of Agronomy Annual Meetings. The following papers were presented by the project staff. The abstracts are published in the 1974 issue of "Agronomy Abstracts."

1. "Nitrogen management of rice in Costa Rica." A. Cordero, D. D. Oelsligle, A. Romero, L. D. Lara and P. A. Sanchez.

2. "Combining corn and soybeans for increased food production in the tropics" by A. M. Pinchinat and D. D. Oelsligle.

3. "Fertilization of forage sorghum in El Salvador" by D. D. Oelsligle, J. Dimas, E. de la Peña and G. Greibel.

4. "Effects of the addition of readily available carbon, phosphorus and inorganic nitrogen on the mineralization of nitrogen in some Andepts of Colombia." by F. Munevar and A. G. Wollum II.

5. "Effects of land clearing methods on crop performance and changes in soil properties in an Ultisol of the Amazon Jungle of Peru" by C. E. Seubert and P. A. Sanchez.

6. "Management research on Peruvian Amazon soils utilizing Sechura rock phosphate" by C. Valverde.

7. "Rates and depth of incorporation of limestone to correct aluminum toxicity in an Oxisol of Central Brazil" by E. Gonzalez, E. J. Kamprath, G. C. Naderman, Jr. and W. V. Soares.

8. "Adverse soil-water conditions and corn production in Central Brazil" by J. M. Wolf, G. Levine, G. C. Naderman, Jr. and E. Gonzalez.

9. "A survey of the natural fertility status of Brazilian soils under Cerrado vegetation" by A. S. Lopes and F. R. Cox.

Seminars were given during the year at the Brasilia Experiment Station primarily for local colleagues by Messrs. Gonzalez, Wolf, Pruntel, Yost and Bandy concerning the results and methodology of their work.

A seminar on the Yurimaguas project was presented by Dr. Sanchez upon invitation by the Universidade Federale Rural do Estado do Rio de Janeiro on July 1. Discussions on possible extrapolative work at their jungle station in Amapá were held. The entire project was presented to the EMBRAPA staff in seminar by Drs. Kamprath, Naderman and Sanchez on July 9 in Brasilia.

b) Impact on National Research Programs

1) As a result of this program's activities, EMBRAPA, the new national research organization, requested NCSU to develop a plan for establishing a Cerrado Research Center. A proposal was prepared in September 1974 and was approved in its entirety as the operational plan for the Center.

2) The results of the Yurimaguas project have been used as a model for future research activities in jungle areas of Peru, Brazil, Ecuador, Colombia and Venezuela. Many requests for cooperation, including on-site visits have been received.

3) Activities on multiple cropping in Costa Rica and Peru have been used for developing the CATIE Cropping Systems research contract.

4) The fertility-capability soil classification system is currently being tested in Colombia, El Salvador, Ecuador and the United States.

c) Impact on Farm Practices

The fertilization program of forage sorghum in El Salvador is being used by small dairy farmers.

4. Feedback

The Project Leader's office has received about 300 requests for publication and information, from all regions of the world during this year. All requests are honored. Continuing communications are held with scientists from practically all tropical American continents, and some Asian and African countries. In effect an informal network on tropical soils research is in operation. Frequent communications are maintained with other U. S. universities and international centers.

5. LDC involvement

A project of this nature involves a high degree of collaboration and participation of a host of other institutions. Each of the specific experiments is actually a cooperative effort with at least one other institution.

In the Campo Cerrado, the field work is conducted at the Brasilia Experiment Station as a joint project with Cornell University and the Empresa Brasileira de Pesquisas Agropecuarias (EMBRAPA), formerly DNPEA. The AID Mission in Brasilia has contributed substantially to this project by providing excellent logistical support. In the Amazon Jungle, the field work is conducted in cooperation with the Dirección General de Investigaciones Agrarias of the Ministry of Agriculture at the Yurimaguas Experiment Station with supporting laboratory and greenhouse work at La Molina. The International Potato Center plays a major role in providing administrative and logistical support to this project.

In Central America, joint projects are conducted with the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) at Turrialba, Costa Rica; the Ministerio de Agricultura y Ganadería of El Salvador; and the U. S. Peace Corps throughout Central America. The logistical support is provided by CATIE including excellent faculty housing and laboratories.

Region-wide research is conducted in cooperation with several institutions, mostly on a scientist-to-scientist basis. Much of the research on the fertility-capability soil classification system was conducted in cooperation with ISFEIP staff plus Peruvian and Brazilian scientists. The data needed for the economic analysis

was provided by the Costa Rican Ministry of Agriculture and EMBRAPA. The soil characterization studies also involved the Instituto Agronómico de Campinas, the Universidad de Costa Rica, the Instituto Geografico Augustín Codazzi, CIAT, and the Ministerio de Obras Públicas of Venezuela. Soil samples for the microbiology, fertility, and chemistry studies were obtained in cooperation with the Instituto Colombiano Agropecuario.

A complete list of individuals cooperating with us appears in the Technical Annual Report. They include both representatives of local institutions as well as international institutes such as IICA and CIP.

The above-mentioned personnel participate in project planning, execution of field work, analysis and reporting of data. The degree of involvement however, is greater at the planning stage by coordinating or administrative LDC personnel in order for the experiments to mesh with national objectives and priorities as well as this contract's objectives. LDC participation in the actual field work is improving in Brazil and Perú in spite of personnel and budget shortages. The situation in Brazil has been resolved satisfactorily recently, but in Perú it is still a serious limitation. In Central America, LDC personnel involvement in the execution of field work is excellent.

In many cases, ongoing experiments have or will be completely taken over by LDC institutions with limited advisory role from our project staff. This is indicated in the attached work plan.

8. Work Plan for the Coming Year

1 to 4. Anticipated Accomplishments, Procedures, Significant Factors, Involvement of LDC Personnel and Institutions

A specific list of research projects is outlined on Table 1 as a means for accomplishing the research objectives Each activity involves one or several experiments. The starting dates, "milestones" and expected completion appear in Table 1. The narrative of each activity follows.

Activities under each objective are interdependent Additional activities might be identified in the course of research as needed for accomplishing the objectives. A certain amount of flexibility is needed when interpreting this table, because research contracts cannot be planned with as much precision as the table might imply. Unless otherwise specified field activities are to be conducted in Yurimaguas, Perú, for Objective 1, in Brasilia, Brazil for Objective 2, in Central America for Objective 3 and on campus on Objective 4.

8.1 Objective 1

1. Characterization of Amazon Jungle Soils. 1* Studies on Colombian Amazon finished January 1973. 2. Field studies on Peruvian Amazon Jungle completed 3 Detailed soils map of Yurimaguas Station expected to be completed by September 1975. Further activities contemplated include characterization of potential extrapolation sites. Requests for cooperation received from Pucallpa and Iquitos (Perú), Amapá (Brazil), eastern Ecuador Project personnel involved in characterization study of soils in the Venezuela Amazon with financial support from Venezuelan government. Personnel: S. W Buol, E. J. Tyler. LDC cooperators: S. T. Benavides, C. Valverde, C Zamora, M. Camargo.

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*These numbers refer to the "milestones" of Table 1.

2. Effects of land clearing methods on soil productivity. 1. Field research at Yurimaguas completed. Results show the advantage of the traditional slash and burn system over mechanized land clearing. Report in preparation. Expected completion December 1975. Personnel: P. A. Sanchez, C. E. Seubert, C. E. Lopez. LDC collaborators: C. Valverde, M. Nureña.

3. Continuous cropping systems and changes in soil properties. Started August 1972. Expected completion: 10 years. Experimental design consists of four consecutive yearly land clearings with four cropping systems and fertilization strategies to be tested as a function of age after clearing. Changes in soil properties associated with fertility depletion are measured. This is the central, long term experiment to develop cropping systems. To date, the first three land clearings have been carried (Milestones 1, 2, 3). The fourth is planned for July 1975. In addition to yield data collection, intensive soil and plant sampling taken at regular intervals monitors changes with time. Results so far indicate that continuous cropping is economically feasible in these jungle Ultisols and that adequate to excellent yields of upland rice, soybeans, cassava and pastures have been obtained with moderate amounts of fertilizers and lime. Personnel: P. A. Sanchez, C. E. Seubert, C. E. Lopez, H. Villachica, C. Langley, LDC collaborators: C. Valverde, M. Nureña.

4. Fertility requirements for pasture production in the Jungle: Two forage experiments with *Panicum maximum* are evaluating the nitrogen, phosphorus, and lime requirements, including an evaluation of urea, sulfur-coated urea and Stylosanthes guyanensis as the source of nitrogen, superphosphate and several rock phosphates including Bayovar rock.

1. Results of first 10 months indicate high yield levels with low P and lime rates and a promising response of sulfur-coated urea applications every six months. Feeding quality of forage determined by nutrient analysis and in-vitro digestibility in cooperation with the Animal Science Department. A third experiment comparing methods of lime and phosphorus incorporation in exhausted pastures was initiated in 1974. 2. Expected completion of this phase in the field. An additional phase consisting of animal evaluation is needed. Personnel: P. A. Sanchez, C. E. Lopez, C. Langley. LDC cooperators: C. Valverde.

5. Fertility requirements of multiple cropping system for food production: This project aims at developing information for the second component of the "model farm": intensive food production for subsistence purposes and local marketing. Experiments in progress in: 1. Intercropping effect on nitrogen fertilization x spacing in corn-soybeans-cassava intercropping. 2. Residue management at different fertility levels in corn-soybeans-cassava intercroppings. 3. Residue management at different fertility levels in corn-soybeans-rice succession. 4. Lime response and depth of liming in corn-cowpea intercropping and monocultures. 5. Fertility requirements for intensive cropping systems ranging from one to five crops a year. 6. Germplasm introduction and testing of materials received from CIAT, IITA, CATIE, and other sources. Preliminary results to date indicate a highly beneficial effect of incorporating Kudzu as green manure on yields and nodulation by soybeans. Personel: M. K. Wade, P. A. Sanchez.

6. Major element responses in principal food crops: Responses to P, K, and lime by upland rice, soybeans, cassava and plantains. The purpose is to establish the needed application rates and critical soil

test levels. Termination of field experiments expected by September 1975. Completion of work expected by December 1975. Personnel: G. S. Miner, D. Anderson.

7. Sulfur and micronutrient requirements: The initial continuous cropping experiment demonstrated the existence of sulfur, boron and molybdenum deficiencies in these soils. 1. Greenhouse tests in Raleigh confirmed these deficiencies and identified zinc and copper deficiencies. Field trials expected to start in March 1975. Data suggests that sulfur and micronutrient deficiencies might be crucial limiting factors. If so their solution with small quantities of inputs transportable at low costs seems economically feasible. Personnel: H. Villachica, P. A. Sanchez. LDC collaborators: C. Valverde.

8. Potential use of Bayovar rock phosphates in the Jungle: Perū is recently beginning to mine huge rock phosphate deposits in Bayovar on the Coast. Its potential is naturally believed to be for acid soils, most of which are in the jungle. Although Bayovar rock is included as treatments in certain experiments in projects 4 and 5, a systematic evaluation of its reactivity fineness and residual effects is needed to ascertain whether this product could be used effectively in the Jungle. Government officials have keen interest and partial financial support has been obtained by Dr. Valverde from MINEROPERU. Preliminary greenhouse experiments are in progress in Raleigh and in Lima by counterpart personnel. Field experiments are expected to be planted by March 1975. Personnel: H. Villachica, G. S. Miner, P. A. Sanchez. LDC collaborators: C. Valverde, J. Davelouis, M. Cano.

9. Developing of a "model farm" for continuous cropping in the Amazon: To be started in 1976. A synthesis of all findings into a model

based on annual slash and burn of 2 hectares of which 80% would be in pastures and 20% in intensive multiple cropping. To be done with actual farmers from the Yurimaguas cooperative. Complete agronomic and economic records will be kept of both crop and animal production. Personnel: To be hired.

10. Cooperative experiments in other areas: To be started in '975. Conducted primarily by cooperators in other areas of Peru and possibly Brazil and Ecuador. NCSU's role will be primarily advisory and cooperative. The purpose of simple experimental trials will be to determine how the Yurimaguas results can be extrapolated to other Jungle areas and what local adjustments are necessary. Personnel: S. W. Buol, P. A. Sanchez, vacant: to be hired. LDC collaborators: several.

8.2 Objective No. 2

1. Soil Characterization. 1. Determination of the potential area of extrapolation in the Campo Cerrado by Cline and Buol. 2. Work continuing in Llanos Orientales in collaboration with CIAT. 3 and 4. Expected additional studies in sites for potential extrapolation. Personnel: S. W. Buol, L. Mejia. LDC collaborators: M. Camargo, J. Spain, R. Guerrero and others.

2. Depth of Liming and Residual Effects. A long term experiment was initiated in December 1972, to evaluate the effect of different lime applications and the potential benefits of liming to 30 cms. depth. Results to date (1) indicate that deep liming is superior to shallow lime application because it increases root development and allows plants to withstand dry periods better. Two crops are grown per year and preliminary indications of the residual effects (2) indicate that relatively low rates are adequate. Several more years are needed to evaluate this

effect in economic terms. Personnel: Kamprath, Gonzalez, Salinas, Naderman. LDC staff: Soares, Lobato, Galrão.

3. Phosphorus Rates, Placement and Residual Effects: A long term experiment was planted in October 1972 to evaluate the effect of rates, placement and timing methods. Results to date suggest that large applications have a marked residual effect and that a combination of an original broadcast application followed by banded applications at each successive planting might be recommendable, but more data is needed for economic analysis. Considerable progress is expected by mid 1975 (1) although a much longer time span is needed for a thorough evaluation. Personnel: Kamprath, Yost, Naderman, Langley. LDC staff: Soares, Lobato, Galrão.

4. Zinc Rates and Residual Effects: A third set of long term experiments was planted in Brasilia in October 1972. They are designed to evaluate the rates, variety and pH interactions of zinc applications. Results to date (1) indicate that about 3 kg Zn/ha is essential to obtain yields and that liming of pH 6.4 induces additional zinc deficiencies. The residual effects of such applications should be adequately established by early 1978. Personnel: Cox, Lopes.

5. Phosphate Sources - Silicate Applications: Field experiments were established in October 1973 to evaluate cheaper sources of phosphorous including native rock phosphate and fused phosphate silicates (Termofosfato) on a pasture grass and legume at three lime levels. Two greenhouse experiments are also evaluating the interaction between lime, phosphorus and silicates with emphasis in decreasing phosphorus fixation. No preliminary results are available but considerable progress is expected by mid 1976 (1) and 1978 (2). Personnel: Kamprath, Yost, Naderman, Smyth, Sanchez.

6. Varietal and Species Differences in Tolerance to Al and low P. A series of culture solution studies in Raleigh were conducted to characterize varietal differences in corn, rice and beans. Results to date quantified such varietal differences and related them to differential ability to take up and translocate phosphorus. A series of experiments are in the process of being installed in Brasilia to test a large number of germplasm for Brazilian sources at three levels of P and three of exchangeable aluminum. Collaboration with Cornell plant breeder, C. O. Grogran is expected. Personnel: Salinas, Sanchez, Naderman, Jackson.

7. Distribution of Properties of Cerrado Soils: A total of 565 samples were taken throughout the Cerrado in order to quantify the variability in chemical properties. Results to date (1) indicate a very good correlation between several fertility parameters and native vegetation. Extreme low fertility characterizes the large majority of the samples. Work will serve as a guide for extrapolation of experimental results. Expected completion in late 1975. Personnel: Lopes, Cox.

8. Chemistry and Mineralogy of Phosphorus Fixation: Basic studies, using modern techniques are needed to better understand the process of phosphorus fixation by iron and aluminum oxides and hydroxides which is the main fertility limiting factor in these savanna Oxisols. Basic laboratory experiments were initiated in Raleigh to understand the process. Considerable progress is expected by late 1975 and completion by mid 1977. Personnel: Buol, Bingham.

9. Sulfur, Potassium and Magnesium Studies: These elements are also limiting in these soils and information in their behaviour and requirements are needed. A proposed series of experiments starting in October 1975 and terminating in 1978 would provide the necessary data. Personnel: Kamprath, others.

10. Extrapolation Studies: Similar to item 10 of Objective 1, to be conducted in close cooperation with other institutions such as the Cerrado Center of EMBRAPA, CIAT in Colombia and in other acid savanna areas. Personnel: Buol, Kamprath, Naderman, others.

8.3 Objective 3.

1. Soil Characterization: Soil toposequence relationship in volcanic areas of Costa Rica completed by mid 1974 (1). Additional studies for new experimental areas planned. Personnel: Buol and assistants.

2 to 8. Experiments in the process of completion of termination by the end of present contract period.

9. Nitrogen Management in Intercropping Systems: A series of corn-soybeans systems were compared with monocultures at different nitrogen levels to estimate efficiency of utilization and other parameters. Results of first set of experiments (1) indicate significant intercropping effect in Turrialba. Other experiments programmed for other regions. Expected completion by mid 1978. Personnel: Oelsligle, McCollum, Rossiter and others.

10 to 12. Phosphorus, Sulfur and Liming Management in Intercropping Systems: A proposed series of experiments to be conducted in important intercropped areas of Central America to determine the dynamics of P, S, Ca, Mg and Al in intercropped systems and what are the best ways to apply these nutrients or amendments. Long term experiments in which considerable progress is expected by mid 1978 but economically-sound interpretations at a later date. Personnel: McCollum, Rossiter, Oelsligle and others.

8.4 Objective 4. (As stated in section 2.b)

1 and 2. Essentially completed during the present contract period.

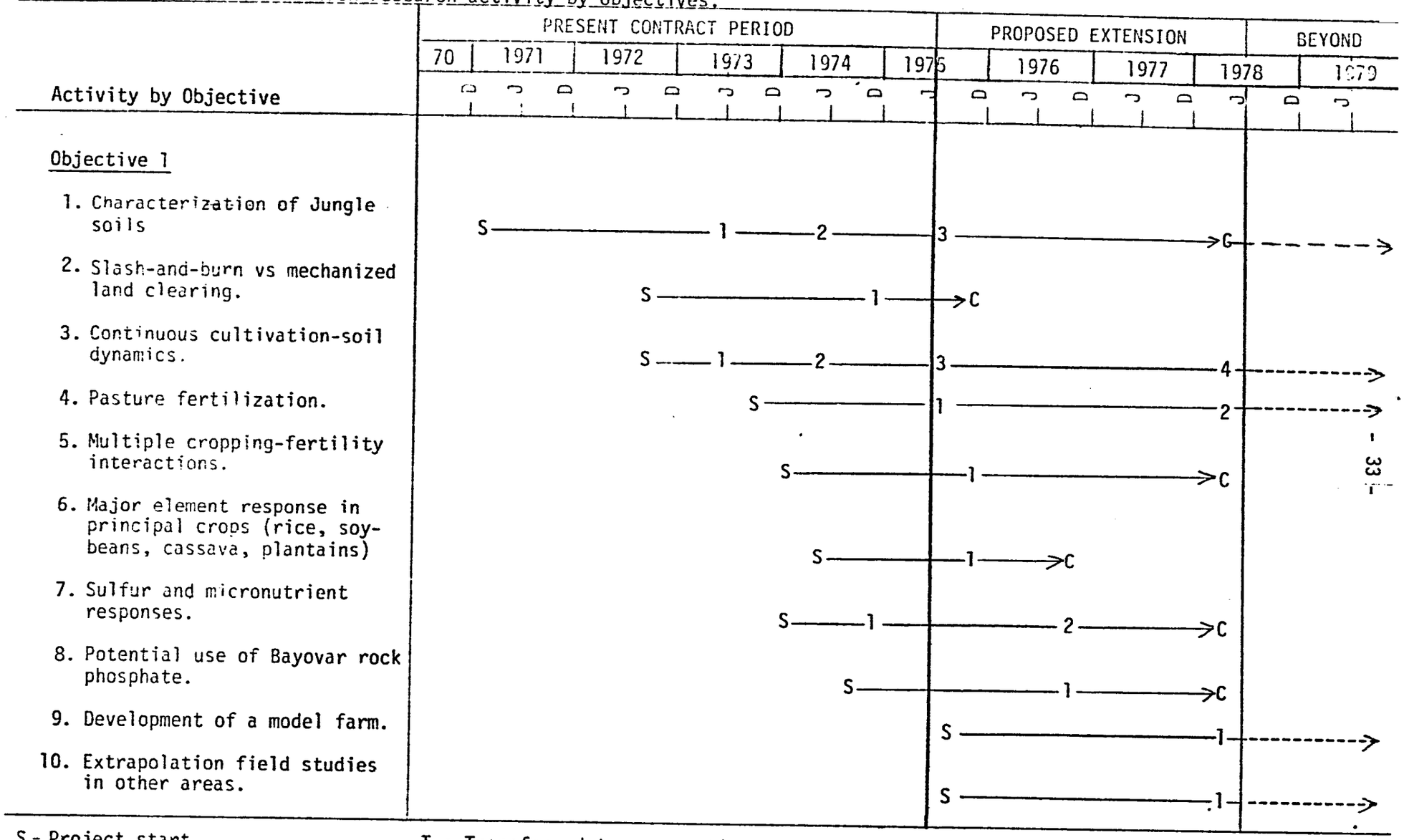
3. Economic Interpretation of Field Results: Economic research has shifted from the analysis of data gathered prior to the contract to analyzing the data produced by the field research activities. It involves translating the agronomic research results in economic terms and additional related data such as transportation costs. The economist will consult with the agronomist annually to 1) review field experimental plans with respect to adequacy for generating economically-useful data and 2) assist in the economic analysis of previously generated data. Personnel: Perrin and assistants.

4. Fertility-Capability Classification System: The system presented in 1971 went through preliminary evaluation in 1973 (1) and the first formal version (2), is expected to be published in 1975. Evaluation of Brazilian data is also finished. Additional evaluation and interpretation is planned using existing data for experiment stations in the tropics as well as in the U. S. Personnel: Granger, Pope, Buol, Sanchez. LDC Cooperators: Benavidez, Bejarano and others.

5 and 6. Greenhouse, Laboratory and Soil Characterization Studies: Needed to answer basic question passed by the field research or estimate degree of data extrapolation. Personnel: Kamprath, Buol, Cox, McCollum, Sanchez, Wollum, Perrin and assistants.

7. Publication and Distribution of Results: Annual technical report and reprints of publications mailed to over 450 individuals and institutions. Personnel: Sanchez, Monar.

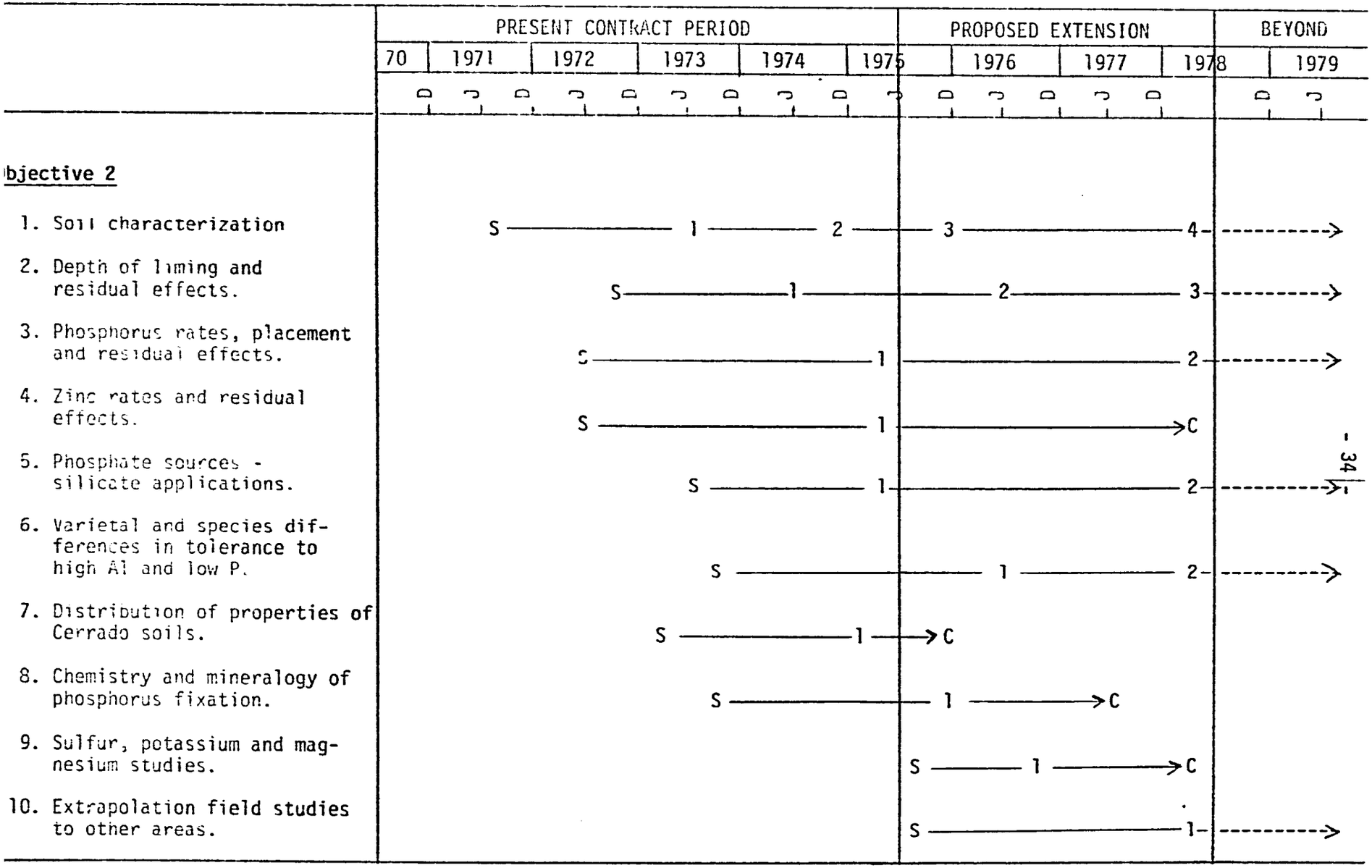
Table 1. Timetable for each research activity by objectives.

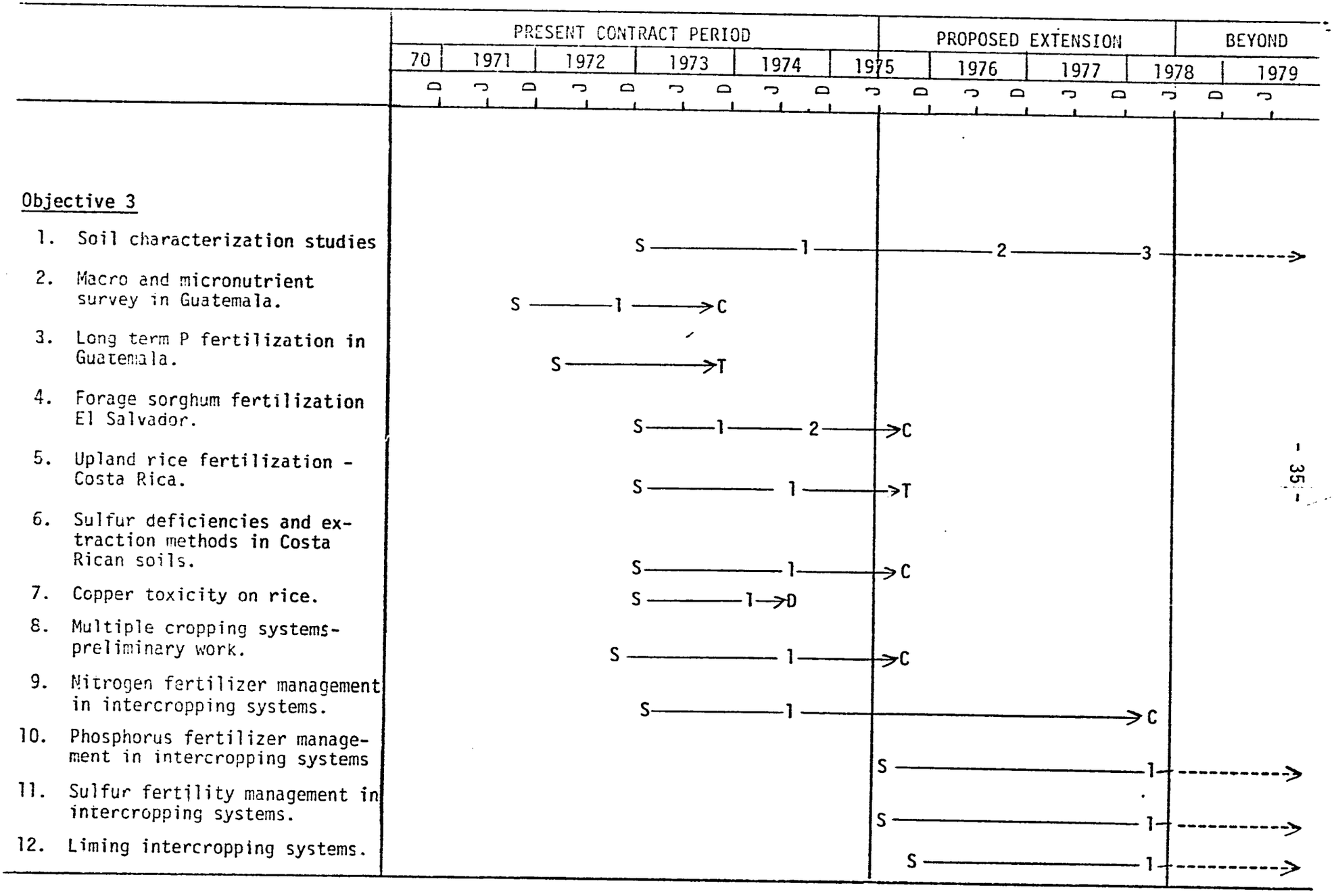


S = Project start
1 = Significant accomplishment
C = Project concluded
D = Project discontinued

T = Transferred to cooperating national institution; limited advisory activities afterwards.

ɜtable - page 2




PRESENT CONTRACT PERIOD
PROPOSED EXTENSION
BEYOND
70
1971
1972
1973
1974
1975
1976
1977
1978
1979
Objective 3
1. Soil characterization studies
2. Macro and micronutrient survey in Guatemala.
3. Long term P fertilization in Guatemala.
4. Forage sorghum fertilization El Salvador.
5. Upland rice fertilization - Costa Rica.
6. Sulfur deficiencies and extraction methods in Costa Rican soils.
7. Copper toxicity on rice.
8. Multiple cropping systems-preliminary work.
9. Nitrogen fertilizer management in intercropping systems.
10. Phosphorus fertilizer management in intercropping systems
11. Sulfur fertility management in intercropping systems.
12. Liming intercropping systems.
S
1
2
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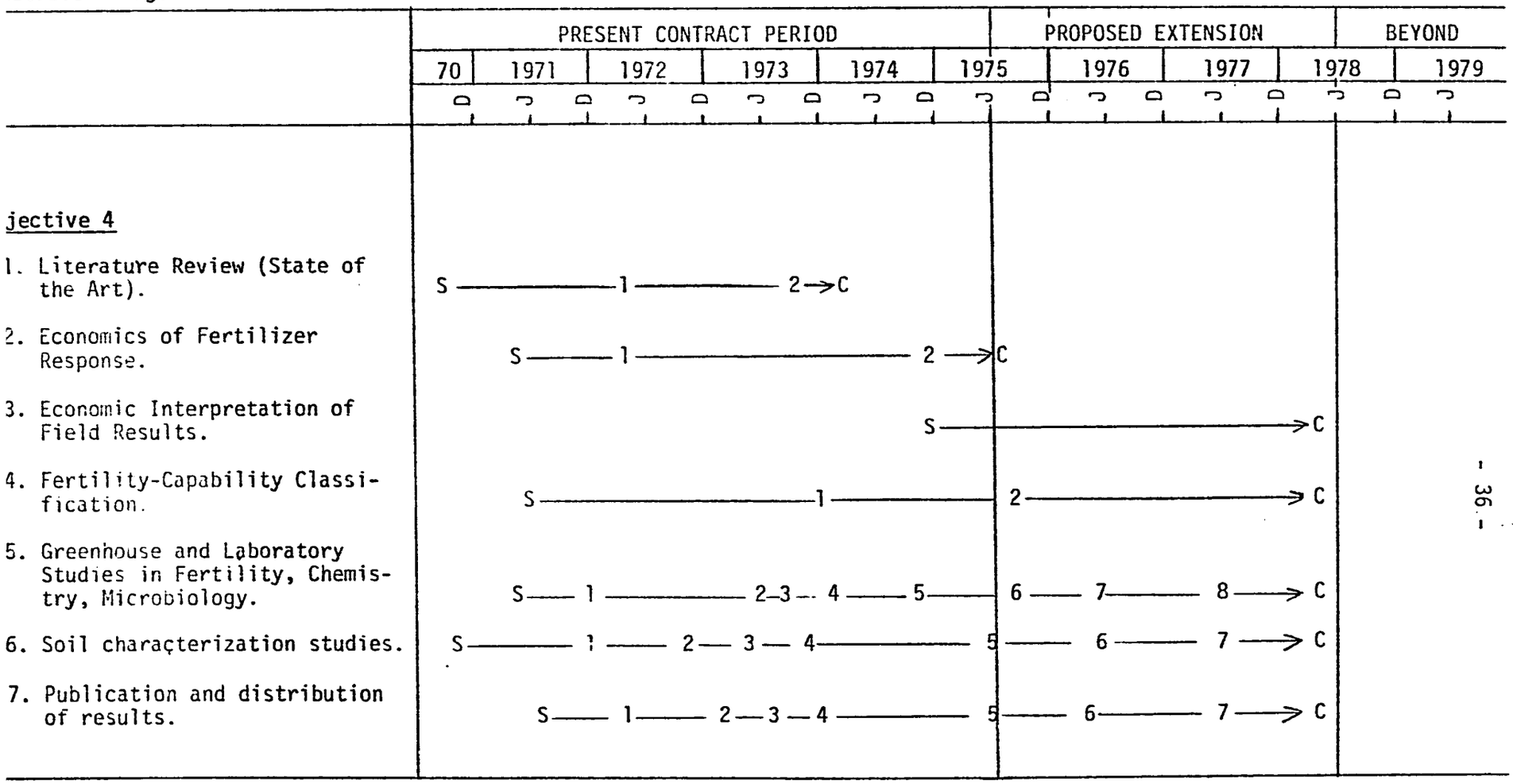
PRESENT CONTRACT PERIOD
PROPOSED EXTENSION
BEYOND
70
1971
1972
1973
1974
1975
1976
1977
1978
1979
D J D J D J D J D J D J D J D J D J
jective 4
1. Literature Review (State of the Art).
S 1 2 C
2. Economics of Fertilizer Response.
S 1 2 C
3. Economic Interpretation of Field Results.
S C
4. Fertility-Capability Classification.
S 1 2 C
5. Greenhouse and Laboratory Studies in Fertility, Chemistry, Microbiology.
S 1 2 3 4 5 6 7 8 C
6. Soil characterization studies.
S 1 2 3 4 5 6 7 C
7. Publication and distribution of results.
S 1 2 3 4 5 6 7 C

5. Proposed Budget

Effective in 1972 the budgeting year starts on April 1. The following is a summary of the obligations and expenditures from the beginning of the Contract to the last budgeting period and the amount requested for the next 12 month period.

	Actual and Estimated Expenditures	
Object	1-1-74 through 12-31-74	7-1-70 through 12-31-74
Salaries and wages	156,936	468,205
Fringe benefits	11,269	38,723
Overhead	63,417	194,908
Consultants	0	4,150
Other Direct Costs	66,576	127,709
Equipment, Materials, Supplies	45,937	102,833
Travel, Transportation, Allowances	51,890	91,835
TOTAL	396,025	1,028,360

G. Involvement of Minority Personnel and Women

1. Blacks: Dr. M. A. Granger (Research Associate).
2. Spanish: Dr. P. A. Sanchez (Associate Professor), Miss B. Monar (Secretary), Messrs: A. Cordero, E. Gonzalez, I. Lepsch, A. S. Lopes, C. E. Lopez, L. Mejia, F. Munevar, J. R. Paredes, J. G. Salinas, R. Schargel, J. H. Villachica (Research assistants).
3. Orientals: S. C. Chang (Research Assistant).
4. Women: B. I. Monar, D. M. McDonald (Secretaries), C. L. Langley (Research technician).

The 17 individuals named above make up 51% of the total NCSU faculty and staff assigned to the project. All research assistants are working towards M.S. or Ph.D. degree. No special problems have been encountered. North Carolina State University is strictly following the Affirmative Action plans.

H. Smithsonian Science Information Exchange. (See attached).

Other Attachements

Research Papers with abstract input sheets.

Financial Report as required in general provisions of the Contract.