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SOIL FERTILITY PROGRAM IN CENTRAL AMERICA

FINAL REPORT

Contract AID/596-203-T ROCAP

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INTRODUCTION

In the fall of 1963, the Agency for International Development (AID) asked North Carolina State University (NCSU) to undertake a soil fertility program in Central and South America to ascertain the fertilizer requirements of the different regions in respect to soil conditions, crops grown, climatic conditions, social-economic conditions, etc. An initial survey indicated very little fertilizer or lime were being used and very little information existed relative to use of fertilizer, lime or other soil amendments to increase crop production. A project was then initiated to introduce a soil fertility evaluation program within each of the cooperating countries. This involved developing facilities needed for getting needed information and the training of personnel in the techniques of soil fertility evaluation and improvement. To accomplish the goal of the project, NCSU stationed two soil scientists in Central America. One was located in Guatemala and worked also in Honduras and El Salvador. The other was located in Costa Rica but also was responsible for the program in Nicaragua. The program became known as the NCSU International Soil Fertility Evaluation Project (ISFEI).

There were six aspects or phases of the ISFEI program:

1. Sampling. Obtaining representative soil and plant samples from the condition about which information is needed is extremely important.
2. Laboratory Analysis. A good laboratory must have accuracy and speed.
3. Interpretation of the Analytical Results. What do the figures mean in terms of nutrient needs of crops?
4. Making Recommendations. This involves good management practices based on available information.
5. Putting the information into use or educational activities.
6. Research.

Since a good laboratory is the backbone of a good soil fertility program, the initial step was to create a good laboratory within each of the cooperating countries. Laboratories were established in each

of the five countries of Central America, and training given to their technicians on techniques to follow. The next steps receiving attention were sampling and data interpretation.

In order to obtain the needed data quickly for interpretative purposes, a technique was introduced which was the reverse of the generally followed procedures. Instead of going to the field first with fertilizer trials, soil samples were collected and completely analyzed in the laboratory. The next step was to conduct sorption or fixation studies to ascertain how much reaction, if any, would take place between the applied fertilizer and the soil. This information was very helpful in determining rates of application of the various elements needed in the soils. After completion of the sorption studies, potted plant studies were conducted to verify nutrient element deficiencies. Armed with the laboratory and greenhouse information, field trials were designed to test the information relative to biological response and to obtain data for economic interpretation. Following these procedures, the time required to obtain the information needed to interpret the analytical results was greatly reduced.

Much progress was made in fertilizer technology, in soil fertility evaluation technology and in land management practices during the period of 1960 to 1975. Many contributions to the soil fertility evaluation technology were made from information gained by the ISFEI program. Techniques that were employed were modified from time to time as new concepts and information became available.

Considerable progress in soil fertility evaluation was made in each of the five Central American countries, but the amount of progress differed considerably from one country to another. The programs in Costa Rica and Guatemala had progressed the most. They had good laboratories and good technicians. A number of field trials and potted plant studies had been conducted in each country for correlation with soil and plant analyses. The greatest problem remaining in these countries was getting the information into use.

The least progress was in Honduras and Nicaragua. Laboratories had been established in both countries, but the facilities and support

were inadequate. Honduras indicated they were going to build a new laboratory and new greenhouses to support the program. Good progress had been made in El Salvador, but constantly changing personnel hindered the program. Apparently, the financial support was inadequate for the program.

A soil fertility evaluation program is a continuous program. The information gained is needed for each crop the farmer grows. When the NCSU/AID Contract relative to soil fertility evaluation came to a close in 1975, much follow-up work was needed in the Central American countries so that the progress that had been made would not be lost and more progress made in each of these countries. There were two great needs: (1) To keep the program moving in Guatemala, El Salvador and Costa Rica; and (2) to move the programs forward in Honduras and Nicaragua so that they might equal the programs in the remainder of Central America.

When the ISFEI program came to a close in 1975, members of the team initiated their own corporation which was named Agricultural Environmental Systems, Inc. in order to keep together the expertise gained the previous decade in their program. The corporation was geared to undertake programs both within the United States or abroad. ROCAP readily recognized the need for the continuation of the soil fertility evaluation program, especially for the support of the ROCAP-sponsored small farmer program. Therefore, a contract was signed March 29, 1976 between the Regional Office for Central American Programs of the Agency for International Development (ROCAP) and Agricultural Environmental Systems, Inc. (AES) which had two major objectives:

1. To transfer the expertise gained in the ISFEI program to the Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) in order that CATIE might act as the backstopping agency for soil fertility evaluation programs in each of the five Central American countries in the future; and
2. To further strengthen the programs of soil fertility evaluation in the five Central American countries but especially in Honduras, Nicaragua and El Salvador.

I. AES PERSONNEL

AES Field Project Management

In the contract, it was agreed that AES would designate one of its on-site men who was fully familiar with the methodologies and techniques developed in the ISFEI program and with ROCAP countries to serve as leader of the program for the ROCAP region. As leader, he would be responsible for organizing and directing technical aspects of the program. He would also serve as the contact man for AES with ROCAP and be responsible for the preparation of all the reports agreed upon in the contract.

Dr. James L. Walker, who worked with the ISFEI program in Central America since its inception in 1974, certainly was the logical choice for this leadership position in the ROCAP region. In order that Dr. Walker could work closely with CATIE, he was transferred from Guatemala to Costa Rica where he was given an office in CATIE in Turrialba.

The second position in Central America at the close of the NCSU contract was held by Dr. John J. Nicholaides, III, but he returned to the NCSU campus on another assignment. The second position for the region was then filled by Dr. Ronald B. Stryker, a graduate of NCSU, who was familiar with the ISFEI concepts and techniques. Dr. Stryker was assigned to Honduras where he reported in the early fall of 1976.

II. LOGISTIC SUPPORT

Both CATIE and AES had project agreements with ROCAP relative to the soil fertility program and the transfer of information gained by the ISFEI program to CATIE. An agreement was also signed between CATIE and AES in order to establish a direct relationship to achieve the goals of the program. It was agreed that there would be full coordination and integration of the AES and CATIE staffs in this project which included activities in laboratory and greenhouse and in field trial development, design, implementation, management, data analysis and interpretation.

Research under this cooperative agreement was to be oriented and coordinated in order to produce fertilizer use alternatives which were suitable for the crops and cropping systems of the small farmers of Central America.

Included in the agreement was logistic support to be given the AES staff by CATIE. The logistic support included obtaining duty free privileges for household effects, personal car, etc., for office space, secretarial help, library privileges, laboratory, and greenhouse space.

III. SCOPE OF WORK

Contract Purpose

The purpose of the contract was to improve the National Soil Fertility Research Programs in the five countries of Central America. As a basis for achieving this goal, AES had the responsibility of: (1) transferring the methodologies that had been developed by the ISFEI program; and (2) continuing to work on a direct basis with the National Soil Fertility programs within the five Central American countries. Special emphasis was to be directed also to preparing recommendations on the use of organic and inorganic nutrient fertilizer materials for use by the small farmers.

General Scope of Work

A good laboratory for soil and plant analyses is the backbone of a good soil fertility program and is usually considered to be the first step in initiating a soil fertility program. Soil and plant laboratories had been established already by the ISFEI program in each of the five Central American countries. Thus the first step in transferring expertise to CATIE was to establish a comparable laboratory which could serve not only to do analyses for research purposes, but could also serve to monitor the laboratories in the five countries. To do this, of course, the laboratory has to be able to do very accurate analyses and to do them rapidly.

Continuation of technical assistance to each of the five Central American countries involved: (1) continuous supervision of the laboratories to be certain they were maintaining good standards of analyses; (2) upgrading of laboratories as new equipment and techniques became available and the training of new personnel; (3) initiating and designing greenhouse and laboratory experiments to obtain more correlation data on specific nutrient element problems; (4) offering guidance in conducting

field trials, especially on small farms; (5) reviewing data, both locally and within other comparable areas to improve recommendations on use of lime, fertilizer and other soil amendments; and (6) organizing and conducting both formal and informal training courses.

Pert Network

The two principal agencies involved in this program were CATIE and AES, but many other agencies were involved also. These agencies included:

1. Agency for International Development (AID/W)
2. Regional Office for Central American Programs (ROCAP)
3. North Carolina State University (NCSU)
4. Cooperating country Soil Fertility Project Personnel (SFP)
5. Participating Agency Service Agreement-USDA (PASA)

In order to achieve the goals of the project within the short period of two years, it was necessary to prepare an outline of activities and responsibilities. Many of the activities were dependent upon the successful completion of previous activities. Thus it was very important that duties and responsibilities be specifically assigned. During the first three months of the contract, a Pert Network was prepared and reviewed by the various cooperating agencies. This briefly outlined the activities to be undertaken, the target date for completion and the agencies responsible. The major activities as outlined in the Pert Network included: (1) establishing an adequate laboratory at CATIE; (2) acquainting CATIE personnel with ISFEI and AES techniques and procedures; (3) setting up a greenhouse at CATIE for potted plant studies; (4) acquainting CATIE personnel with potted plant techniques as developed by the ISFEI program; (5) establishing field trials within the five countries to obtain needed information; (6) conducting seminars and training sessions for personnel from the five Central American countries; (7) cooperation between CATIE, PASA and AES personnel to develop soil analogs with the cooperating countries which will greatly strengthen the soil fertility program.

IV. PROJECT ACTIVITIES

In view of the large number of agencies and people involved directly or indirectly in this project, the goals outlined in the Pert Network were remarkably well achieved. Changes in personnel within cooperating countries, a lack of personnel--even within CATIE--often hampered progress, but the goals as outlined above were achieved for the most part.

CATIE Laboratory

Part of an older building previously occupied by the Nuclear Energy Project was renovated with funds from the CATIE/ROCAP project to house the new soil-plant analysis laboratory. The changes involved installation of lab benches, utility lines including water, electricity and air, plus a general painting and cleanup job. This was done under the supervision of Dr. J. L. Walker, who was responsible for the arrangements of the laboratory. In addition to the laboratory, soil and plant sample preparation, sample storage and chemical storage rooms were prepared in this building. Offices for the laboratory director and for Dr. Walker were renovated in the building also.

Equipment

At the close of the ISFEI program, there was considerable equipment for laboratory and office, and for the preparation of visual and audio aids at NCSU. After obtaining permission from the AID Contract Office in Washington, all of the equipment that was usable was shipped to CATIE in Turrialba for use in the new soil-plant laboratory. The shipment included:

Laboratory Equipment:

1	Perkin-Elmer model 290 Atomic Absorption instrument
2	pH Meters
1	Torsion balance
1	Mettler balance
1	Coleman spectrophotometer
1	Hotplate
1	Portable air compressor
1	Vacuum pump
1	Wiley mill

Multiple-Unit Apparatus including: 2 dispensers; 1 stirrer; 1 titrator; 6 diluters; 1 pH apparatus; 1 washer; 4 lab carts; 48 carrying trays; and 144 sample trays

Office Equipment:

2 IBM electric typewriters

3 Model 241 Dictaphones

1 Transcribing unit

1 Portable dictating unit Model 848

1 Model 224V Sharpe calculator

Visual Aid Equipment:

1 35 mm Slide projector with case and slide trays Kodak Ektagraphic

1 Sony portable stereo cassette--recorder system with speakers and case

1 Eumig Vienette 8 mm Camera with optasound casette recorder for preparing sound movies

1 Eumig Mark 810D 8 mm movie projector

1 8 mm Yashica camera

1 Wollensak tape recorder

Dr. A. H. Hunter of the AES staff met with Dr. Walker (AES) and Dr. Rufo Bazán (CATIE) to review the equipment available and its condition, and to ascertain other equipment that would be needed to get the laboratory operational. One of the first items that was obviously needed was a source of pure water. Dr. Hunter recommended the installation of a reverse osmosis system rather than a steam still. He supplied the details of equipment needed and where it could be purchased. Other items required included a new Atomic Absorption instrument and additional multiple-unit apparatus, soil crusher, multiple stirrer, 3-aliquot dispensers, additional carts and measuring spoons. These items were purchased for the laboratory by CATIE with CATIE/ROCAP funds. The new apparatus was assembled and checked out upon arrival at the lab by Dr. Stryker and Dr. Walker

Laboratory Personnel

Since CATIE had no soil-plant laboratory for routine analysis, neither did they have anyone to operate it. Upon the recommendation of

Dr. Walker, CATIE hired Ing. Roberto Díaz-Romeu to serve as the laboratory director. This was an excellent choice since Ing. Díaz had participated in one of the NCSU-sponsored Soil Fertility Evaluation Seminars for seven weeks in Raleigh and had worked in the soil-plant laboratory for a few years in Guatemala. Thus Ing. Díaz was familiar with the laboratory, equipment, techniques and procedures of the ISFEI Project.

The CATIE laboratory now is adequately equipped for routine analysis of soil and plant material, and is one of the better laboratories in Central America. It has the capability of handling more than 300 samples per day if two or three more technicians are added to the staff. Since it is not the purpose of this laboratory to service farmers, it will not be necessary to add the additional staff. The lab can monitor other labotories in Central America and hold training sessions for new personnel in the other laboratories.

Greenhouse-Shadehouse

An important step in a soil fertility evaluation program is using potted plant studies to correlate with laboratory procedures for ascertaining nutrient needs in soils. Climatic conditions in Central America, and especially Turrialba, are such that heat is not required for greenhouses. A screen-enclosed shadehouse with a fiberglass or clear plastic roof works very nicely. A greenhouse-shadehouse was built adjacent to the laboratory building, especially for the use of the soil fertility program. The shadehouse was constructed similarly to one built adjacent to the soils-plant laboratory in San Jose that had been constructed earlier through efforts of the ISFEI program.

In the greenhouse-shadehouse studies, the techniques developed by the ISFEI project were adopted. These involve using small volume (7 or 9 oz.) styrofoam cups holding only 200 or 300 ml of soil. The moisture level is maintained in the soil by insertion of cellulose fiber wicks into the bottom of the cups. This alleviates the problem of watering over weekends or holidays and assures more uniform watering between treatments.

The missing nutrient technique as developed by Hunter (AES) was introduced into use in the shadehouse. In this technique, an optimum treatment is projected from information gained from laboratory studies.

Then all other treatments receive the optimum treatment. If the laboratory analysis indicates a sufficient quantity of an element is present in the soil, then this element will not be added to the optimum treatment. However, one treatment will include the optimum treatment plus this one element, just to be certain the laboratory analysis was correct in predicting no response. If the laboratory analysis indicates the soil is deficient in an element, then it is added to the optimum and to all other treatments except one. Through this procedure of laboratory analysis first, followed by a potted plant study, much information can be quickly obtained which will greatly improve field trials. This is true of all field trials including variety trials as well as fertility studies.

Training Sessions and Seminars

One of the most effective activities of the ISFEI program was conducting a seven-week seminar each summer to fully discuss the six aspects of a soil fertility program: (1) sampling; (2) laboratory analyses; (3) interpretation; (4) recommendations; (5) putting information into use; and (6) research. Approximately one week was devoted to each subject. A decision was made to hold similar training sessions at CATIE but to reduce the period of time to four weeks. Three such seminars were planned during the course of the project. The first was to be handled largely by AES personnel, the second by both AES and CATIE personnel, and the third largely by CATIE personnel. The first would acquaint CATIE staff with material presented and the format used in conducting the seminar.

The program for the first seminar held October 3-30, 1976 was prepared by Dr. J. W. Fitts (AES). Two lectures of one hour each were presented in the mornings and was followed by 45 minutes of discussion. The afternoons were given over to laboratory and greenhouse activities under the leadership of Dr. A. H. Hunter and Ing. Roberto Díaz. One-half day and one day field trips were planned and conducted by Dr. Walker (AES) and Dr. Bazán (CATIE). About half the lectures were presented by Dr. Fitts with discussions led by Dr. Walker. The remainder of the lectures were given by Dr. Ron Stryker (AES), Dr. Sam

Portch (AES), Dr. Walker (AES) and M.S. Victor Quiroga (IICA/Costa Rica). The lectures and discussions were tape recorded in order that the information could be retrieved for future seminars.

The 25 participants in the first seminar represented seven countries distributed as follows: Costa Rica 2; El Salvador 4; Guatemala 1; Honduras 7; Nicaragua 7; Panama 2; and Jamaica 2. Expenses for the participants from the Central American countries were paid largely from residual funds of the ISFEI program through the cooperation of NCSU and the AID Contract Office.

Dr. J. L. Walker assumed responsibility for the second seminar held July 18-August 12, 1977. He prepared the program and presented about half the lectures. He was assisted in the lectures and discussions by Dr. Ron Stryker (AES), Dr. Sam Portch (AES), Dr. Enrique Gonzalez (AES-CATIE), Dr. Elmer Bornemiza (Universidad Nacional de Costa Rica), Dr. Rufo Bazán (CATIE) and Ing. Washington Bejarano (CATIE). Dr. Hunter and Ing. Díaz again were responsible for the laboratory and greenhouse studies, with Ing. Díaz assuming a much larger role in the presentations. A total of 42 participants representing 14 countries attended the second seminar with the distribution as follows: Costa Rica 4; El Salvador 5; Guatemala 3; Honduras 9; Nicaragua 6; Bolivia 1; Brazil 1; Ecuador 2, Panama 2; Peru 3; Dominican Republic 1; United States 1; Holland 2; and Jamaica 2.

Instead of holding a third seminar as originally planned, CATIE decided it would be more fruitful to hold three training meetings within the countries in which the straight-line discontinuous model for data interpretation would be explained. Understanding the linear plateau model is particularly important to the research worker doing field work or greenhouse studies. The first of these training meetings was held September 26-29, 1977 in Managua. The second was held in Santa Tecla, El Salvador, October 4-7, 1977, and the third in Tegucigalpa, Honduras November 28-December 2, 1977. The number of participants was about the same for each of the locations: Managua 27; Santa Tecla 28; and Tegucigalpa 24. Dr. J. L. Walker (AES) took the leadership in preparing and presenting the programs and was assisted by Dr. Ron Stryker (AES) and Ing. Washington Bejarano (CATIE).

There was good representation in each of the seminars from the five Central American countries but the representation was particularly good

from Nicaragua, Honduras and El Salvador--the three countries where emphasis was being placed upon strengthening their programs. Without doubt, these seminars laid good groundwork for transferring the ISFEI expertise to CATIE and for strengthening the programs within the five Central American countries.

Sampling

Obtaining representative samples is of paramount importance to a soil fertility evaluation program. If a poor sample is taken, there is no way it can be improved upon in the laboratory. Getting representative samples from small farmers is particularly challenging. A study was made in Honduras to see if a "general" sample could be taken from an area of small farms which might represent several of the farms. In selecting the "general" sample, care was exercised to avoid any unusual conditions such as eroded areas, fence rows, etc. and to keep within the same soil type. In the area studied, the only severe deficiency noted was manganese. Subsequent studies showed farmers' fields in the vicinity of where the general sample was taken were deficient in manganese too. Since little or no fertilizer has been used by the small farmers and since manganese deficiency, no doubt, is a result of a low level in the parent material of the soil, a similarity should exist. The sampling problem, of course, will develop as farmers start using fertilizers and the soil level for the various nutrient elements change.

A question frequently arises relative to the number of cores or subsamples needed for a composite sample. This is particularly true in taking soil samples from fields of small farmers. A sampling study was conducted in Nicaragua in which one up to 20 cores were taken for a composite sample. Considerable variance was noted between the composite samples consisting of less than 6 borings as compared to composite samples of 18 or more cores. This confirms studies in other areas that the number of cores needed is related to the variability of the soil rather than the size of the field. Fields of small farmers usually are more variable--due to management practices--than larger fields of the big farmers.

Field Trials and Greenhouse Studies

Field trials and potted plant studies in soil fertility have been conducted for several years in most of the Central American countries as a result of the ISFEI program. However, there are never enough such trials for all the crops and conditions involved. These trials were continued during the course of this project, but special emphasis was given to Honduras and Nicaragua. Although using laboratory and greenhouse data as a basis for establishing field trials was stressed in the training sessions of the seminars, this procedure still is not generally followed. Some of the reasons for this are different people may be responsible for the laboratory or greenhouse studies and the field trials. Also field trials may not be planned sufficiently in advance to permit conducting the potted plant studies. Nevertheless, the high cost of conducting field trials and the high mortality rate of such trials dictate that a more efficient procedure should be followed. Results of potted plant and field trials conducted during the course of the project have been published by CATIE as listed in the Appendix.

Soil Analogs

In the ISFEI program, the yield equation outlined by Fitts was often referred to in soil fertility evaluation. The equation states that yield is a function of soil, crop, climate and management which includes pest control. Obviously, each major factor can be subdivided into many subfactors, or, simply stated, there are many factors that influence yield. Some of these factors can be controlled and some cannot. Nevertheless, it is very helpful if an evaluation can be given of as many variables as possible. Such information is necessary to predict risks involved in using fertilizers or other management practices. The amount of risk is very important to the small farmer, since he must minimize the number of risks that he can take.

Developing information for soil analogs can be very helpful background information to a soil fertility program. Such information will be useful in making general recommendations, but also would be useful to the soil scientist making specific recommendations based on soil analysis of the plow layer.

CATIE took the leadership in promoting a soils analog subproject in which several soil survey personnel were brought in to work on this program on a short-term basis. Dr. Walker of AES was closely associated with this program, too, and was responsible for recruiting most of the short-term personnel for this program. Reports by these experts have been published by CATIE and are listed in the Appendix.

V. PROJECT REVIEW

In August of 1977, Dr. R. W. Pearson of Auburn University, Auburn, Alabama was contracted to review the accomplishments of the two-year program. Dr. Pearson was an excellent choice for this assignment, since he is not only a well-known and highly respected soil scientist, but he also was somewhat familiar with the ISFEI program and could evaluate the degree to which transfer of expertise had taken place. Some of Dr. Pearson's conclusions in his review were:

1. All of the requirements of the project to date have been completed.
2. The project has had a tremendous impact regionally.
3. The most complete file of data on soil fertility field experiments and soil analogs in Central America is now found at CATIE in Turrialba.
4. The termination of the Contract of the CATIE technicians will retard progress, especially in Nicaragua and Honduras.

VI. PROBLEMS AND FUTURE ACTIVITIES

Moving staff members to new areas of assignment, recruiting new men and moving to new headquarters, acquainting staff with project objectives, logistics of operation, etc. always is a time-consuming, frustrating experience. This is especially true for a short two-year contract. Staff on this project did a remarkable job in mastering all of the headaches associated with new areas and a new project. Very little time was wasted in getting the project underway as evidenced by the speed with which the laboratory was established and the first seminar conducted.

Perhaps the greatest problem encountered was the understaffing in CATIE. Dr. Bazán was the lone soil scientist on the CATIE staff, and

although a capable individual, he had a multitude of duties including administrative responsibilities. The addition of Ing. Díaz to operate the soil-plant laboratory and the potted plant studies was very helpful. The addition of Ing. Washington Bejarano on a temporary appointment during the summer of 1977 was very helpful too. Transferring expertise from one project to another is rather difficult when the recipient is greatly understaffed.

The staffing problem will continue to be the greatest restraint in CATIE assuming responsibilities for guidance and monitoring of the soil fertility programs in Central America. As a bare minimum, Ing. Bejarano should be maintained in a permanent position, and there really should be at least one more full-time scientist added to the staff.

Agricultural Environmental Systems, Inc. has moved their headquarters from Raleigh, North Carolina to Orange City, Florida and has changed the name of the corporation to Agro Services International, Inc. This is more in keeping with activities of the corporation. In their new location, Agro Services International, Inc. has a new "model" soil-plant laboratory, greenhouse facilities, and a nice conference room for conducting seminars or training sessions. Should CATIE need additional backstopping in their Central American program, Agro Services International, Inc. will be ready to lend a hand.

A P P E N D I X

Reports and Publications

CATIE assumed the responsibility of printing most of the reports and publications prepared during the contract. Following are the titles of some of these publications:

1. Metodología de muestreo de suelos, análisis químico de suelos y tejido vegetal e investigación en invernadero.
2. Estudios de invernadero.
3. Proyecto de sistemas de producción para pequeños agricultores: Caracterización de los suelos de los sitios experimentales.
4. Uso práctico de los modelos discontínuos para interpretación rápida de la respuesta de cultivos a la aplicación de fertilizantes.
5. El manejo y resumen de datos de experimentos con fertilizantes en Centroamérica y su relación con los estudios de identificación de suelos con caracteristicas semejantes de manejo.
6. Resumen del análisis y breve interpretación de los experimentos de fertilización de El Salvador, Honduras y Nicaragua. 1960-1975.
7. Soil fertility investigation in Honduras. 1977.
8. Reseña del trabajo sobre suelos análogos en América Central.
9. Metodología utilizada en el aspecto bioclimático.
10. Metodología utilizada en el aspecto suelos.
11. Primera aproximación de suelos análogos de Centro América.
12. Resultados obtenidos de la computación de las variables consideradas para comparar los suelos de El Salvador.
13. Analogias de suelos en Honduras.
14. Los suelos agrícolas de El Salvador de 0 a 500 metros sobre el nivel del mar.
15. II Reunión regional sobre fertilidad y análogos de suelos. El Salvador, marzo 13-18, 1978. Informe Final
16. El Proyecto de fertilidad de suelos del CATIE.
17. Consultant's final report to CATIE and ROCAP on completion of soil analog subproyect.

18. Soil Science in Costa Rica. Classification, fertility and conservation.

19. Soil Science in El Salvador. Classification, fertility and conservation.

20. Soil Science in Guatemala. Classification, fertility and conservation.

21. Soil Science in Honduras. Classification, fertility and conservation.

22. Soil Science in Nicaragua. Classification, fertility and conservation.

23. Soil Science in Panamá. Classification, fertility and conservation.

24. Programa Nacional de fertilidad de suelos del Ministerio de Agricultura y Ganadería de Costa Rica.

25. Análisis del departamento de suelos CENTA, MAG. El Salvador.

26. Programa de Manejo y conservación de suelos. Proyecto de fertilidad de suelos. Ministerio de Recursos Naturales, Honduras.

27. Informe sobre el estado de los programas de fertilidad de suelos IDIAP. Panamá.