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CROP PRODUCTION AND LAND POTENTIAL OF BENCHMARK SOILS OF LATIN AMERICA

Contract AID/ta-C-1158

ANNUAL RESEARCH REPORT
for the period
July 1, 1976 to September 30, 1977

Submitted to the
U.S. Agency for International Development
by the
Department of Agronomy and Soils
College of Agricultural Sciences
University of Puerto Rico
Mayaguez, Puerto Rico

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REPORT SUMMARY

A. 1. Project Title and Contract Number: Crop Production and Land Potential of Benchmark Soils of Latin America - AID/ta-C-1158

2. Principal Investigator, Contractor and Mailing Address:
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3. Contract Period (as amended): January 1, 1975 to December 31, 1980

4. Period covered by Report: July 1, 1976 to September 30, 1977

5. Total AID funding of contract to date: $2,110,555

6. Total expenditures and obligations through previous fiscal year: $248,718.67

7. Total expenditures and obligations for current year: $457,241.69

8. Estimated expenditures for next fiscal year: $444,600.00

B. Narrative Summary of Accomplishments and Utilization

The objectives of the Benchmark Soils Project is to demonstrate that agroproduction technology can be transferred among tropical countries on the basis of soil classification. To verify the transfer hypothesis, a series of crop production and soil management experiments are conducted in various countries by this contract and a parallel project of the University of Hawaii.

A workshop was held in Hawaii to determine the research strategy and experimental design best suited for the projects. Another workshop on project design was held to discuss project management, identify and schedule milestone events, and to plan coordination with the Hawaii project. Guidelines for field and laboratory procedures were developed jointly by the Universities of Hawaii and Puerto Rico.

The soils selected for experimentation by this project are highly weathered, red upland soils of the subhumid tropics defined as Eutrustox in the U.S. Soil Taxonomy. Five experiment sites in such soils were established in Puerto Rico and in Minas Gerais, Brazil. A total of 13 transfer, 6 variety and 8 management experiments have been conducted with maize and soybeans. Exceptionally high maize yields of up to 11,515 kg/ha (183 bu/A) were obtained. In general, maize yields and response to fertilizer were very similar at the Brazil and Puerto Rico sites which reflects positively on the transfer hypothesis.

The Benchmark Soils Project and its concepts received wide publicity at the Latin American Congress of Soil Science held in Colombia, at a seminar held at ICRISAT, India, and at the CLAMATROPS Conference held in Kuala Lumpur, Malaysia. A widely circulated illustrated newsletter informs about project activities at regular intervals.

ANNUAL RESEARCH REPORT

I. General Background

Increased world food production may be accomplished through higher yields per unit area and by expanding the acreage of cultivated land. Since the prime agricultural areas of the temperate region are for the most part already developed, it is imperative that the potentially arable but not intensively utilized land resources of the tropics be brought under cultivation at a faster rate.

The World Food Conference held in Rome in October 1974 focused its attention on the worsening agricultural situation. It emerged at this conference that a concerted international effort is needed to alleviate the present food crisis and to prevent future famines. This action program should involve innovative approaches to the development of advanced agricultural technologies, procedures to guide the selection of land resources to be developed, and a methodology for the transfer of agroproduction technology to these areas.

Agricultural experimentation is both expensive and time-consuming. As many LDC's do not have the professional and financial resources to engage in the extensive research programs needed to create a solid knowledge base for efficient crop production, it appears expedient to capitalize on agricultural experience gained elsewhere.

Time has shown, however, that the extrapolation of agricultural experience generated in developed countries in the temperate zone to tropical LDC's has met with little success.

One reason for this failure is that many soils of the tropics have properties which require management practices that are unique to these soils and do not necessarily conform to the concepts developed for soils of the temperate region. It follows that the process of transfer of agrotechnology to less developed tropical countries must take place predominantly within the tropics. This implies that the advanced production technology to be transferred has to be developed primarily in tropical ecosystems. Although far from being complete, the aggregate knowledge in the area of tropical agriculture is substantial. However, this knowledge is distributed unequally among tropical countries and is frequently not utilized outside its place of origin because it is considered site-specific.

It is the underlying rationale of this research project that soil management knowledge is directly transferable in the tropics on the basis of soil classification. If this hypothesis is substantiated, a strategy for mobilizing and utilizing existing soil management information can be conceived and incorporated in the general model of agrotechnology transfer.

II. Project Purpose and Objectives

A. Project Purpose

In January 1975 a contract was signed between the U.S. Agency for International Development (AID) and the University of Puerto Rico (UPR) to initiate a project entitled "Crop Production and Land Potential of Benchmark Soils of Latin America".

This project bacame popularly known as the Benchmark Soils Project; a name coined from UPR's proposal title and subsequently adopted by the parallel project of the University of Hawaii.

The purpose of the Project is to test an innovative approach to agrotechnology transfer designed to assist LDC's in appropriately utilizing their land resources for increased and better quality food production by bypassing key constraints. The three major constraints prevailing in LDC's are scarcity of qualified research personnel, insufficient capital, and lack of time to close the widening gap between agroproduction and food requirements. The traditional approach to agricultural research is extremely time-consuming. However, the poor farmers in LDC's need the basic information conducive to higher outputs now and cannot wait until locally generated research results become available to them.

The concept under study in the Project is the hypothesis that agrotechnology is directly transferrable among tropical countries on the basis of soil classification, specifically at the family level of the U.S. Soil Taxonomy. (Soil Survey Staff, 1975). The soil family is the lowest category of this comprehensive system of taxonomic soil classification that was developed over the past 25 years by the Soil Conservation Service of the U.S. Department of Agriculture and has been published recently. The soil family constitutes a condensed scientific statement that integrates the knowledge about a soil and its environment. It was conceived with the intent

to group soils having similar physical and chemical characteristics that affect their response to management and which are homogeneous in the parameters important to the growth of plants. Soils belonging to the same family should, therefore, have essentially the same management requirements and responses, and should have similar potentials for crop production. Consequently, the soil family should have the inherent quality of making agrotechnology transfers a possibility.

This concept has been used effectively in the continental U.S. (De Ment, 1971). If proven correct for the tropics, it may well have a profound impact on agricultural development and increased food production. First, available for immediate tapping will be millions of dollars worth of research information produced by thousands of man-years of effort. Second, it will help save millions of dollars by avoiding the duplication of agronomic experiments all over the tropics -- a waste of time, money and effort LDC's can ill afford. Third, it should lead to the formation of a worldwide network of expertise and a Crop Production Reference Center by taxonomic soil units. Fourth, the concept of agrotechnology transfer is not confined to soil management practices but encompasses all associated experience and knowledge; e.g., information on crops and farming systems, water management, erosion control measures, economics of crop production, etc.

B. Research Objectives

The general objective of the Benchmark Soils Project as stated in the contract is "to correlate food crop yields on a network of tropical benchmark soils and to determine scientifically the transferability of agroproduction technology among countries". More specifically, the primary research objectives of the Project are:

1. to demonstrate that soil management knowledge can be directly transferred at the soil family level of the U.S. Soil Taxonomy,
2. to establish that the behavior of tropical soils and their potential for crop production under various levels of management inputs can be predicted on the basis of soil taxonomic units, and
3. to develop a statistical methodology to verify the concept of agroproduction technology transfers via soil classification.

Secondary objectives of the Project are to evaluate the validity of presently used and additional differentiae of soil classification relative to crop production, and to indicate management alternatives conforming to the economic constraints of small farmers of tropical countries.

III. Relevance of Objectives

The contractual objectives as stated and detailed in the preceding section continue to be relevant. The research conducted to date does not indicate the need for modification of the project objectives at this time.

IV. Accomplishment

A. Administration

1. General

The Benchmark Soils Project is assigned to the Department of Agronomy and Soils of UPR's College of Agricultural Sciences at Mayaguez, Puerto Rico. It is administered in accordance with established university regulations as regards authorities, recruitment and remuneration of staff, procurement procedures, and accounting. Since the initiation of the Project, Dr. F.H. Beinroth, Professor of Soil Science, served as Principal Investigator. The organizational set-up of the Project within the university structure is depicted on the chart presented as Appendix A1.

During the first two years the Project has made reasonable progress in creating a functional internal infrastructure conducive to productive research. This required a considerable amount of time and effort as office space was inadequate, laboratory facilities were extremely limited, and sufficient qualified staff was not available at the university.

At the time of contract award only one of the present Project staff, the Principal Investigator, held an

appointment at the Department of Agronomy and Soils. Since January 1975 five new professionals were recruited for the Project and three more were transferred from the staff of the UPR's Agricultural Experiment Station. In addition, one secretary and three field research aides were hired. At the present time the Project maintains a regular staff of nine professionals and four non-professionals, equivalent to 11.75 man-months of effort per month. The Project personnel and their respective responsibilities are shown in a table contained in Appendix A2.

2. Memoranda of Agreement and Subcontracts

A memorandum of agreement between the University of Hawaii and the University of Puerto Rico regarding the cooperation of the two institutions in their respective Benchmark Soils Projects and their technical coordination was worked out and became effective on January 1, 1976. Negotiations with the Empresa de Pesquisa Agropecuaria de Minas Gerais (EPAMIG) led to a project agreement which details the Project's involvement in Minas Gerais, Brazil, and specifies EPAMIG's technical and administrative contributions. After consultation with the USAID Mission in Brasilia, this agreement was effectuated by the signatory institutions on January 26, 1976.

In order to secure expert assistance for the statistical work stipulated in the contract, the Project subcontracted the University of Kentucky to conduct basic

statistical research relative to a model that will provide a satisfactory test for the transfer hypothesis. This subcontract became effective on August 1, 1976 and had a duration of one year.

B. Planning and Coordination

1. Experiment Design Workshop

On the rationale that the experimental design and the research methodology be reviewed and specified prior to initiation of the field work, AID's Research Advisory Committee suggested that a workshop be held on "Experimental Designs for Predicting Crop Productivity with Environmental and Economic Inputs". This workshop was organized by the University of Hawaii with Assistance from the University of Puerto Rico in coordination with AID and was held in Hawaii in May 1974. Thirty-eight invited participants from the United States and abroad attended the workshop and a total of fourteen papers were presented. UPR staff prepared three position papers for this meeting.

The primary purpose of the workshop was to develop the research strategy and experimental designs best adapted to generate the kind of data required to demonstrate the transferability of agricultural experience on the basis of soil taxonomic units and which will allow economic analyses aiding decision processes of small farmers in LDCs. The salient results of the discussions at the workshop were that the experimental design should be a 5^2 partial factorial as

modified by Escobar (Laird and Turrent, 1974) with three replicates, that the experiments should have two soil family-related variables at five levels each, and that maize is to be the indicator crop at all sites.

It became further evident at the workshop that there exists no statistically adequate methodology for testing the transfer hypothesis postulated in the objectives above. The workshop participants therefore recommended that AID be approached to provide a grant to allow a team of statisticians to develop a proper test for transferability. A detailed account of the workshop is contained in a published report prepared by J.A. Silva and F.H. Beinroth (1974).

As elucidated in the following section on experimental field work, the University of Puerto Rico has incorporated all of the workshop recommendations in its research design. The Project has also acted on the recommendation regarding the need for fundamental statistical research by subcontrating the University of Kentucky to conduct the work described below under "Statistical Research".

2. Project Management and Design Workshop

In January 1976, a management and design workshop for UPR's Benchmark Soils Project was held in Puerto Rico under the direction of Mr. R. Kitchell of AID/Washington. In addition to UPR project staff, Dr. L. Frederick of DSB/AGR and Dr. J.A. Silva of the University of Hawaii participated

in this activity. During this workshop all major present and future project activities were identified, associated milestone events were scheduled, and critical assumptions and progress indicators were defined. The results of the workshop were summarized in a 32-page document which proved very useful for immediate and long-term project management.

3. Coordination Meeting

The First Annual Coordination Meeting of the University of Hawaii's and the University of Puerto Rico's Benchmark Soils Project was held in Puerto Rico in August 1976. Key personnel of the Hawaii project and all Puerto Rico project staff were in attendance; also present were Dr. T.S. Gill of DSB/AGR and Drs. F.B. Cady and L.A. Nelson, statistical consultants. The meeting provided the first opportunity for the technical staff of both projects to discuss problems and their solutions, exchange experiences, and plan and coordinate present and future activities. Particular attention was given to management experiments and their relevance to the need of small farmers and plans for utilization.

The Second Annual Coordination Meeting was held in Manila in the Philippines in August 1977. It was attended by twelve staff members of the two Projects; two statistical consultants, Drs. F.B. Cady and L.A. Nelson; Dr. L.D. Swindale of ICRISAT; Drs. T.S. Gill and D. F. Peterson

of DSB/AGR; and Dr. D.N. Moss of AID's Research Advisory Committee. The technical discussions centered on treatment variables, determination of phosphorus levels, plot size, statistical aspects, and experiment methodology. These items are discussed below in the section entitled "Changes in Research Design".

The meetings were extremely useful and complemented the informal technical coordination of both Benchmark Soils Project.

C. Network of Experiment Sites

1. Soils Selected

The soils selected for experimentation are well-drained, red upland soils occurring under savanna or deciduous forest vegetation in subhumid tropical regions. They are slightly acid to neutral, have an appreciable supply of bases and moderate to high base saturation in the subsoil. Among their adverse properties are a limited water holding capacity, a tendency to compact when cultivated with heavy equipment, and phosphorus deficiency. Their main constraint for agricultural use is the insufficiency of soil moisture for more than three months per year.

The soils belong to the group that has been called Laterites, Soils Ferrallitiques or Latosols in recent years and is now referred to as Oxisols in the U.S. Soil Taxonomy. The particular kind of Oxisols chosen for the Project are Tropeptic Eutrustox of the clayey, kaolinitic,

isohyperthermic family. This family was selected because it is common to both Puerto Rico and Hawaii and thus provides the required link between the two Benchmark Soil Projects. Although not the most common kind of Oxisols, they are extensive in tropical South America and Africa. They represent important soil resources preferred for immediate development over other Oxisols on account of their high base saturation status.

2. Search for Sites

In theory, the locations for field experimentation should be randomly selected from all the units of the population of soils comprised in the stated soil family. In the Project, however, random sampling is not feasible, primarily because only a limited number of countries can be involved. On the basis of preliminary investigations involving literature surveys and consultations, the search was concentrated on Brazil, Colombia, the Dominican Republic, Jamaica and Venezuela. All others countries of tropical America were excluded because the changes of locating the desired soil family there were nil or because of political considerations as in the case of Cuba. The findings of the soil identification efforts were as follows.

Brazil. After considerable field and laboratory studies Tropeptic Eutrustox of the clayey, kaolinitic, isohyperthermic family were identified in the northern part

of the state of Minas Gerais. Such soils were found to occur also in the state of Parana. However, mean annual temperatures are somewhat lower there causing the soils to be classified into the isothermic rather than isohyperthermic family. The Project acknowledges the excellent cooperation of Mr. M. Camargo of the Servicio de Levantamento e Conservacao de Solos of EMBRAPA in the process of site selection.

Colombia. Oxisols are extensive in the Llanos Orientales of Colombia, but the on-site and analytical studies conducted by the Project showed that Eutrustox do not occur in this area. Drs. R. Guerrero and A. Leon of the Instituto Colombiano Agropecuario assisted the Project in Colombia.

Dominican Republic. With the aid of Dr. P. Arens of FAO and Mr. F. Ferreira of the Centro Nacional de Investigación, Extensión, y Capacitación Agropecuaria, several field trips were made in the Dominican Republic to inspect and sample soils. However, justified expectations to corroborate the existence of kaolinitic Eutrustox in this country could not be substantiated by the field and subsequent laboratory studies. The Project regrets this fact as both the Government of the Dominican Republic and the USAID Mission had expressed interest in having this country included in the network of research sites.

Jamaica. The Project consulted with Dr. Guy Smith, former Director of Soil Survey Investigations of USDA-SCS, who recently classified the soils of Jamaica according to the U.S. Soil Taxonomy. His correlations indicate that although

several classes of Oxisols exist in Jamaica, there are none that belong to the family required by the Project.

Venezuela. Since Oxisols are of major extent in eastern Venezuela, a search for Eutrustox was initiated there with the cooperation of Dr. J. Comerma of the Centro Nacional de Investigaciones Agropecuarias. Again, the scrutiny of existing detailed soils surveys and voluminous analytical data failed to reveal the presence of any Eutrustox. For the most part the Oxisols of Venezuela are acid and sandy and thus unsuitable for inclusion in the network; a situation that also holds true for neighboring Guayana.

3. Establishment of Experiment Sites

In light of the results of the soil investigations described above, it is obvious that the establishment of experiment sites on Tropeptic Eutrustox in tropical America had by necessity to be confined to Puerto Rico and Brazil. Two types of sites were established in these countries, primary and secondary sites. The characteristics of each of these kind of sites are explained in the following section.

In Puerto Rico, one primary and one secondary site were installed on the grounds of the Isabela Agricultural Experiment Substation of the University of Puerto Rico in 1975. This 120-hectare research station, is located in the northwestern corner of the island and was founded in 1928 to serve the Isabela Irrigation District. Since then a vast amount of research has been conducted there on sugarcane, vegetable crops, grains, fuit crops and subsistence crops.

In Brazil, one primary and two secondary sites were established in 1976 and 1977, respectively, in an area adjacent to the San Francisco River in northern Minas Gerais known as the "Distrito Agro-Industrial de Jaiba". This 300,000-hectare irrigation scheme was recently developed and is now being opened for colonization by small farmers. The Project sites are thus well located from the point of view of local impact and utilization. The primary site near Jaiba is on a new experiment farm operated by the Project's cooperating agency, EPAMIG. The two secondary sites are on private land nearby. A preliminary survey and soil sampling for an additional primary site near Janauba in Minas Gerais has been completed. It is expected that the pending soil analyses will be affirmative and that lease arrangements will be negotiated in the near future.

4. Progress in Relation to Contract Agreement

The contract between AID and the University of Puerto Rico called for the establishment of three primary sites during the initial contract period of three years. At this point in time, two primary sites have been established and are operative in Puerto Rico and Jaiba, Brazil, respectively.

The contract further stipulated the establishment of three "satellite" sites for each primary site. However, in view of statistical and pedological considerations the concept of satellite sites was subsequently modified. In consultation with two statisticians it was decided at the

annual coordination meeting that a combined total of eight sites per soil family, including primary and secondary sites, will suffice to adequately test the transfer hypothesis. The Project has presently established five sites and will add another site this year. Since the parallel project of the University of Hawaii is in the process of establishing two sites on the Eutrustox family, a total of eight sites will be in operation by 1978 as required for statistical reasons.

Although a wider geographical spread of the experiment locations involving more countries would have been desirable, this was physically impossible to achieve in Latin America. However, through the linkage with the project of the University of Hawaii, the Eutrustox network encompasses clusters of experiment sites in three widely separated regions--Oceania, South America and the Caribbean.

D. Experimental Field Work

1. Research Design and Methodology

The research design and methodology was developed in concurrence with the recommendations of the Workshop on Experimental Design (Silva and Beinroth, 1974) and in close coordination with the University of Hawaii. In the Project design distinctions are made between two types of experiment sites, designated primary and secondary sites, and three kinds of experiments referred to as transfer experiments, variety trials and management experiments, respectively.

Primary sites are experiment locations where all of the three kinds of experiments are conducted and which are completely instrumented for collection of pertinent weather data. At each primary site the following weather parameters are monitored: (1) ambient temperature and relative humidity recorded continuously with standard hygrothermographs, (2) daily maximum and minimum ambient temperatures, (3) rainfall recorded continuously or daily, (4) accumulated daily solar radiation, (5) daily wind run, (6) pan evaporation (optional), and (7) maximum-minimum soil temperatures at 5, 15, 20 and 50 cm depths. In so far as possible, instrumentation is according to U.S. Weather Bureau Standards.

Secondary sites are experiment locations where only transfers experiments are conducted. They are required to increase the number of experiment sites per soil family in order to have sufficient data for a statistically valid estimate of the effect of uncontrolled variables on crop yields. Secondary sites may differ from primary sites in that they exhibit variations in soil properties important to plant growth, such as pH or base saturation, within the range permitted by the definition of the soil family. If located at some distance from the primary site, secondary sites may also have different weather conditions. In this case they are equipped with the standard instrument shelter, hygrothermograph, raingauge and solar radiometer. At other

secondary sites, situated closer to the respective primary sites, only rainfall is recorded, as other weather parameters are not likely to vary significantly over short distances.

Transfer experiments are soil fertility trials designed especially to generate the data necessary to test the hypothesis set forth in the purpose of the project. Their design is the 5^2 partial factorial modification by Escobar as described in a paper by Laird and Turrent and presented at the Workshop on Experimental Design. Currently the two variables on Eutrustox are phosphorus and nitrogen at 5 levels each with 13 of the 25 total possible treatment combinations and 3 "control" treatments as shown in table 1 (see Appendix). These 16 treatments are replicated at least 3 times; thus, there are 48 plots in each experiment. Such transfer experiments are conducted on all primary and secondary sites. In order to eliminate or at least minimize the effect of the natural moisture variable, trickle irrigation systems are installed for all transfer experiments. Tensiometers are used to determine the frequency of water applications. This way soil moisture is maintained at or near optimum levels throughout the growth period. Both maize and soybeans have been used as test crops in earlier transfer experiments, but only maize is now used. Varieties known to be well adapted are planted in the transfer experiments at each location.

Variety trials are conducted at the primary sites to assure that a well adapted and productive variety is

grown in the transfer experiments at all locations. Also, to make the yield data among sites more comparable, the test crop varieties of each site of the network are included in the variety trials at each primary site.

In the variety trials a split-plot design is employed, each variety being grown with phosphorus treatments at two levels, "optimum" and -0.85 (see table 1). With all other controllable conditions at or near optimum, this provides a measure of each variety's requirement for and capacity to respond to applied phosphorus.

Management experiments have the purpose to provide information on economic and efficient practices, and information for subsequent soil interpretations and land capability classification. Whereas the procedures for conducting the transfer experiments must be virtually identical at all sites, the design of the management experiments is more flexible and allows the project to respond to host country priorities and to local farmer needs. A philosophic frame work for the management experiments was developed at the first annual coordination meeting of the UH and UPR projects in 1976. Particular attention is paid to experiments on costly inputs and high energy use cultural practices, such as irrigation, fertilization and tillage.

Field operations, and data collection and processing follow standardized procedures to ascertain compatibility of results throughout the network. Working in close

cooperation with the University of Hawaii, a set of guidelines was developed and is continuously revised so that laboratory and field experiment procedures can be as nearly identical as possible within the constraints confronted at the various experiment sites of each project. These guidelines are sufficiently detailed to insure comparability of data obtained at all sites. All field operations such as land preparation, pest control, irrigation, cultivation and harvesting are considered, as well as field plot designs and data observations. Special attention has been given to make standardization of climatological data collection. Each of the experiments is statistically analyzed in consultation with the Project's statistics experts. The University of Hawaii assumed the responsibility for the overall analyses.

2. Progress and Status of Field Experiments

a. Puerto Rico

Transfer experiments. Prior to initiating transfer experiments a uniformity trial using soybeans (variety Woodworth) as the test crop was established in July 1975 on the primary site at Isabela, Puerto Rico. The main purpose of this planting was to observe the apparent uniformity of the soil in the field selected and to delineate areas unsuitable for experiment plots. Several such areas were located and can now be avoided when subsequent experiments are installed. A secondary purpose was to "draw down" the fertility to a more nearly common level before establishing

transfer experiments. Soybean yields appeared to be relatively uniform across the field but samples from 10 m x 10 m plots indicated a range in yields from 1,141 kg/ha (17 bu/A) to 2,249 kg/ha (33.5 bu/A) with no fertilizer.

Six standard transfer experiments with maize and four with soybeans have been completed in Puerto Rico; three with maize and two with soybeans at both the primary and the secondary sites. In the first transfer experiment at the primary site, the mean yields of maize (variety X 306 B) over three replicates ranged from 6,590 kg/ha (105 bu/A) to 11,515 kg/ha (183 bu/A). These can be considered very good to excellent yields for maize grown in the tropics. There was a marked increase in yield with the first increment of phosphorus, a further increase with the next increment but no further significant increase with higher levels of phosphorus. There appeared to be no response to applications of potassium. Maize yields with the same variety were lower on the secondary site, but the trends were similar to those found on the primary site. The data from these and subsequent transfer experiments with maize are shown in tables 2,3,4 and 5 in Appendix B.

Soybean (variety Jupiter) yields at the primary site were severely reduced by an unexpected attack of Anthracnose (Colletotrichum dematium var. truncata) which caused complete defoliation of the plants about 2 weeks before physiological maturity. A further reduction of yields in the high fertility plots reflected the severe lodging caused

by the higher fertility treatments which produced more luxuriant growth. At the secondary site, soybean yields of a shorter stature variety (Hardee) were more satisfactory and ranged from 2,361 to 2,872 kg/ha (35 to 43 bu/A). There were no significant differences in grain yields among treatment, however, in this experiment. Yield data from subsequent transfer experiments with soybeans show inconsistent response to applied phosphorus and potassium. Grain yield data for the soybean experiments are presented in tables 7,8,9 and 10 in Appendix B.

Both maize and soybeans have shown a marked early positive growth response to phosphorus applications, as is evidenced by plant height measurements at 30 days after planting, (table 13, Appendix B). This effect was less apparent in later observations. Low-phosphorus and "control" plots in the maize experiments exhibited weak stalk development and considerable lodging. Moderate to high phosphorus treatments resulted in severe lodging of the Jupiter variety of soybeans grown in the first transfer experiment on the primary site. Because of this and the previously mentioned Anthracnose attack, subsequent plantings have been with an INTSOY selection of the soybean variety, Hardee.

Variety trials. Three maize variety x phosphorus level experiments have been completed at the primary site at Isabela. These trials included twenty-six varieties from Australia, Cental America, Hawaii and the Philippines which were studied at two levels of phosphorus. The mean grain yields from the first of these trials ranged from 4,395 kg/ha

(70 bu/A) up to 10,210 kg/ha (162 bu/A) with the Pioneer hybrid X304C. The two more commonly grown local, open pollinated varieties Mayorbela and Diente de Caballo yielded 6,719 kg/ha (107 bu/A) and 7,010 kg/ha (112 bu/A), respectively, at the lower level of phosphorus and did not respond to the heavier application rate. In more recent trials, Pioneer hybrid X304 continued to rank highest although yields were lower. This hybrid exhibits other good agronomic attributes such as resistance to lodging, insects and diseases and has, therefore, been selected to replace variety 306B for subsequent transfer experiments with maize in Puerto Rico.

Management experiments. A phosphorus level x variety x plant population factorial experiment with soybeans was conducted in cooperation with INTSOY. This experiment was prompted by apparent deficiencies in the first transfer experiment with the Jupiter variety of soybeans where, at the suggested plant population, medium and high phosphorus levels caused severe lodging resulting in significantly lower grain yields. It is anticipated that this and a similar follow-up experiment currently underway will provide information suggesting desirable plant population and soil fertility levels for three important soybean varieties grown in the tropics. The grain yield data from the first of these experiments are presented in table 12, Appendix B.

In another management experiment plots were plowed at different soil moisture levels to find ways to improve seedbed preparation for soybean plantings. The results of this experiment are detailed in a M.S. thesis by H.R. Merino Garcés

and summarized in table 14, Appendix B. With approximately 21% moisture in the soil at the time of the first plowing, the number of large clods remaining after final seedbed preparation was significantly less than when soil moisture was 23% or higher. The improved seedbed resulting from plowing at the lower soil moisture level increased seedling emergence, plant counts at 25 days, and subsequent grain yields.

To examine the feasibility of placing phosphorus fertilizer in bands in the plant row, thereby reducing markedly the overall application rate, a P placement experiment with maize was planted. This experiment was only recently harvested and the data are not yet statistically analyzed.

b. Brazil

In May 1976, Mr. C.E. Seubert, UPR agronomist, was transferred to Brazil and now resides near the primary site at Jaiba, Minas Gerais. He succeeded in establishing excellent rapport with the cooperating institution, EPAMIG and the USAID Mission in Brasilia. The cooperation and support of both EPAMIG and USAID/Brasilia have been exceptionally favorable to the development of the Jaiba sites.

The establishment, preparation and instrumentation of the primary site was essentially completed by September 1976. Through the intercession of EPAMIG, the Project obtained two small houses from RURALMINAS, a local development agency. These are used for offices and a laboratory, and for storage of fertilizer and equipment. The required weather instruments and laboratory and field equipment was imported with the help of USAID/Brasilia. Arrangements are under way

with EPAMIG and Brazilian customs authorities for the shipment of additional materials and equipment. EPAMIG provided the Project with a jeep-like vehicle and a surplus Chevrolet Carryall was made available by USAID/Brasilia. Later, two more vehicles were provided by the same agencies.

By September 1976 an irrigation well had been installed at the primary site on the EPAMIG experiment station (Paraná) at Jaiba. Water tanks and a trickle irrigation system were installed with the assistance of Dr. J. Keller of Utah State University who served as a consultant to the Project. The drilling of wells at each of two secondary sites has also been completed and pumps have been installed. One of these wells is a relatively good water source yielding about 17,600 l/hr with only a 1 m water level drop. The other well is weaker, but adequate for a secondary site.

Transfer experiments. The first transfer experiment with maize (variety IAC Phoenix 1110) was planted in October 1976. A soybean experiment was established one month later with the same variety used in Puerto Rico (Jupiter). The results of these experiments are summarized in tables 6 and 11 in Appendix B. A new transfer experiment with maize, variety Cargill 111, was planted at the primary site in May 1977. The first transfer experiments with maize at the two secondary sites at Jaiba will be planted in November.

In the initial experiments at Jaiba, maize and soybean yield responses were mostly limited to the first level of applied fertilizer, as was the case in Puerto Rico. In Brazil, however, the first increment of fertilizer produced a much more marked

yield increase than in Puerto Rico. Apart from the very high yields obtained in the first experiments planted at Isabela and the extremely low yields in Brazil without fertilizer, maize yields at the two locations have been very similar.

Variety trials. A maize variety trial including 46 varieties was planted in October 1976 and harvested in March 1977. Thirty-six of these varieties were recommended and provided by the Centro Nacional de Pesquisa de Milho e Sorgo (CNPMS) in Sete Lagoas, Minas Gerais, as they constitute the national maize trial tested throughout Brazil. The other ten varieties have been selected from those included in the variety trial conducted in Puerto Rico and material suggested for the area by CNPMS.

Mean yields of the highest ranking twelve varieties are shown in table 15, Appendix B. Although this trial was not irrigated, yields of the top twelve varieties were very good and consistently above 7 metric tons per hectare (110 bu/A). With irrigation and additional phosphorus, mean grain yields were still higher, ranging from 7.7 to 9.9 tons per hectare (123 to 157 bu/A) in a maize variety x phosphorus experiment with five varieties and four levels of phosphorus (table 16, Appendix B). A second maize variety x phosphorus level experiment has been completed recently.

The standard INTSOY variety trial which comprises sixteen soybean varieties was planted in November 1976. The grain yields of some varieties were outstanding. The top-ranked seven varieties produced from 3.2 (Clark) to over 4.4 (Davis) tons per hectare (50 to 70 bu/A) as illustrated in table 17, Appendix B. Another soybean variety trial was planted in June 1977.

Management experiments. One management experiment with maize was installed at the primary site in October 1976. It was designed in close cooperation with EPAMIG and responded to local research needs. The interactions between row spacing, maize variety and plant population were studied at three levels of each variable and replicated four times. High populations of 40,000 to 60,000 plants per hectare increased grain yields with row spacings of 50 to 75 cm. But, in-row crowding apparently reduced yields at the highest population density of one variety but not the other (table 18, Appendix B). An irrigation experiment and a phosphorus x nitrogen level experiment have also been recently completed at Jaiba.

E. Statistical Research

From a statistical point of view, the success or failure of the project rests heavily upon whether a transferability test can be developed and applied. However, as indicated above it transpired at the Workshop on Experiment Design that a statistically satisfactory method to test the transfer hypothesis was not available.

In recognition of this fact, AID provided financial support for a meeting of three statisticians, Drs. R.L. Anderson, F.B. Cady and L.A. Nelson, to discuss an appropriate approach to the problem. At this meeting progress was made on developing the nucleus of what promises to be a procedure for a transferability test. A tentative statistic was formulated the main elements of which are the prediction sum of squares,

the prediction sum of squares with expectation, and the mean square residuals. However, considerable work remained to be done regarding the mathematical details of the test to evaluate some of its properties.

In concurrence with a recommendation by AID's Research Advisory Committee, the University of Puerto Rico therefore subcontracted with the University of Kentucky to conduct the theoretical studies needed. Under this subcontract, Dr. Anderson and associates are engaged in the research outlines below:

1. Method of Prediction
   a. Investigate biasis estimators (of regression parameters) concerning their usefulness in prediction.
   b. Applications to actual data sets
2. Develop a Valid Test of Transferability Hypothesis
3. Statistical Properties of the Proposed Test Statistic
   a. Distribution under null hypothesis
   b. Power of the proposed test against some specific alternatives
4. Applications of the Test Procedure to Project Data.

Since the development and evaluation of the test of the transferability hypothesis depends on the form of the

estimator used, actual yield data generated by the Project are needed to verify the model now being developed. A first evaluation will be possible when more yield data from both the Brazilian and Puerto Rican sites become available.

F. Changes in Research Design

The deliberations at the Second Annual Coordination Meeting held in Manila in the Philippines in August 1977 resulted in various changes in the experiment design. On the basis of previous experience, the following decisions affecting the UPR project were taken.

1. Maize will be the sole indicator crop for all transfer experiments. Soybeans have been dropped as a test crop in transfer experiments but may be used in management experiments.

2. Nitrogen and phosphorus will be the variables in tranfer experiments. Nitrogen will replace potassium as the second variable for Eutrustox because no consistent response to K has been found in previous experiment. The source for nitrogen will be urea.

3. The levels of phosphorus applications will be determined as follows. For the first planting of transfer experiments in a new area, P-isotherms will be made on a block basis for composite samples from individual plots to determine P application rates. Based on the P-isotherm for a block, the amount of P sorbed at 0.01 ppm P in solution

will be determined. This value will be converted into kg P/ha and used as the + .40 level of P treatments. The other application rates of P will be calculated rather than determined from the P-isotherm curves.

For subsequent transfer experiments on the same plots, P-isotherms will be made for individual plots as originally described.

4. The plot size will be augmented to 2 x 8 m, and there will be 16 treatments.

G. Project Review

In February 1977, an AID-appointed panel conducted an on-site review of UPR's Project. Dr. W.M. Johnson, Deputy Administrator for Technical Services of the Soil Conservation Service, USDA, headed the team; the other members were Dr. R. Dudal, Director of the Land and Water Division of FAO, and Mr. J.R. Moffett, Food and Agriculture Officer of USAID/Bolivia. Dr. T.S. Gill represented the Office of Agriculture of AID's Development Support Bureau. The review team visited the Project's experiment sites in Minas Gerais, Brazil and then proceeded to Puerto Rico to inspect the field work conducted there and to meet with Project staff and UPR officials. The review team reaffirmed the validity of the concepts and research strategy of the Project and commended the accomplishments. It felt that an expansion of the network to other countries and additional soil families should not be considered at this time. The review panel also recommended a three year's extension of the Project.

H. Linkages

Linkages are considered an essential element of the Benchmark Soils Project and their establishment has been actively pursued since its inception. In the course of site selection, contacts were established with numerous institutions and individuals in LDC's and in the U.S. These have already been mentioned in the previous section on Network of Experiment Sites.

In addition to the basic linkage with the parallel project of the University of Hawaii, collaborative agreements and/or formal linkages have been effectuated with the following institutions:

Empresa de Pesquisa Agropecuaria de Minas Gerais (EPAMIG). This agency is the Project's principal cooperator in Brazil. In coordination with the national research institution, EMBRAPA, EPAMIG is responsible for all aspects of agricultural research in the state of Minas Gerais. The president of EPAMIG, Dr. H. Mattana Saturnino, fully concurs with the principles and approach of the Project and realizes the potential benefits for the agricultural development of the state of Minas Gerais. Dr. Mattana Saturnino was personally involved in the initial negotiations, reflecting his interest in the Project. The administration and staff of EPAMIG have given the Project excellent cooperation.

Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). The Project has established very effective

working relationships with the Servicio Nacional de Levantamento e Conservacao de Solos (SNLCS) of EMBRAPA. SNLCS has expressed interest in getting more directly involved in the Project. As yet informal contacts are maintained with the EMBRAPA administration in Brasilia.

USAID/Brasilia. Efficient rapport has been developed with the AID Mission in Brasilia. Although under no obligation to do so, the Mission provided the Project with valuable cooperation and support which greatly facilitated Project implementation in Brazil.

International Soybean Program (INTSOY). Since soybeans are used as an indicator crop in the experiments, viable linkages have been developed with UPR's AID 211 (d)-soybean grant and the AID-sponsored INTSOY program. Superior working relationships exist between INTSOY's plant breeder stationed in Puerto Rico, Dr. E.H. Paschal II, which resulted in joint field research of mutual benefit.

North Carolina State University. Dr. L.A. Nelson, Professor of Statistics at NCSU, serves as a permanent consultant to the Benchmark Soils Project for matters of statistics and experimental design.

University of Kentucky. The project subcontracted the University of Kentucky Research Foundation to conduct basic statistical research relative to a model that will provide a satisfactory methodology to verify the concept of soil management knowledge transfers on the basis of soil taxonomic units. (See preceding section E.)

Utah State University. The Department of Agricultural and Irrigation Engineering is assisting the project in the design and installation of trickle irrigation systems. Dr. Jack Keller serves as a consultant and visited the experiment sites in Brazil and Puerto Rico.

Consortium on Soils of the Tropics (CST). The Project has a common goal and works closely with CST. The Principal Investigator is also the UPR representative on the CST Executive Committee.

University of Puerto Rico's AID Grant. The Project is closely linked to and complemented by UPR's 211 (d) grant AID/csd-2857 entitled "Classification and Microbiology of Tropical Soils". Under this grant efforts are made to identify and evaluate the advantages and deficiencies of Soil Taxonomy relative to tropical soils. (This state-of-the-art study is carried out with assistance from the sister universities comprised in the Consortium on Soils of the Tropics.) It will also be determined which systems of soil classification are currently used in the tropical countries and how these systems relate to Soil Taxonomy. It is anticipated that the grant will create a keener awareness of the advantageous attributes of Soil Taxonomy among LDC soil scientists which should expedite the utilization of project results.

Informal linkages further exist with CYMMIT, FAO of the United Nations, the Office de la Recherche Scientifique

et Technique Outre-Mer (ORSTOM), the Soil Conservation Service of the USDA, and the University of Ghent, Belgium.

V. Utilization-Related Activities

In its current phase, the Project is in the process of generating the field data needed to test the transfer hypothesis. Dissemination of results is, therefore, premature at this time. However, efforts were made to publicize the existence of the Benchmark Soils Project and to create an understanding of its rationales and potential utilization. To date these attempts were directed mainly at the scientific community.

The Benchmark Soils Projects of the Universities of Hawaii and Puerto Rico and the concept of agrotechnology transfer on the basis of soil classification received wide publicity during an international Seminar in the Use of Soil Survey and Classification in Planning and Implementing Agricultural Development in the Tropics held at ICRISAT in Hyderabad, India, in January 1976. The seminar was organized by the University of Hawaii and co-sponsored by the University of Puerto Rico mainly for planners and soil scientists from LDC's in Asia and Africa. It provided opportunities for eighty soil scientist and land use planners from tropical countries in Africa and Asia to report, discuss and learn about the practical usefulness of the U.S. Soil Taxonomy in relating soil classes to crop

production and agricultural development. The Principal Investigator presented a paper at this seminar (Beinroth, 1976).

Another paper describing the Project was read at the Fifth Latin American Congress of Soil Science held in Medellin, Colombia, in August 1975 (Beinroth and Spain, 1975). This presentation met with a very favorable response and generated interest in the Project. The Principal Investigator also addressed the Work Planning Conference of the National Cooperative Soil Survey held in Orlando, Florida, in January 1977 in a short exposition of the Project.

Many distinguished scientists and educators who visited the Mayaguez Campus were briefed about the Project and discussed various aspects with the staff. Among the visitors were Dr. O. Anderson, Federal University, Vicosa, Brazil; Dr. E. Barragan, University of Navarra, Spain, Dr. R. Howell, University of Illinois; Dr. A. Leon, CIAT, Colombia; Dr. J.W. Peltason, Chancellor, University of Illinois; Dr. P. Quilt, Overseas Development Ministry of the United Kingdom, Trinidad; Dr. J.M. Scholl, University of Wisconsin; Dr. W.N. Thompson, Director, INTSOY, University of Illinois; Dr. G.F. Walton, Dean, Cook College, Rutgers University; and Dr. K.L. Wells, University of Kentucky.

The "Benchmark Soils Project Quarterly" regularly informs about and illustrates ongoing activities, results

and other events of the two projects of the Universities of Hawaii and Puerto Rico. It is a semi-technical newsletter published by the University of Hawaii and is circulated widely in the LDC's of the tropics.

The Project Review held in Brazil in February 1977 received detailed coverage in five important newspapers of the state of Minas Gerais.

VI. Statement of Expenditures

1. Expenditures by Inputs, 7/1/76 to 9/30/77

Line Item	Expenditures
Salaries & Wages	$ 173,603.23
Consulting Fees	1,825.00
Fringe Benefits	17,335.89
Travel & Per Diem	33,045.38
Equipment	67,361.78
Materials, Supplies & Services	58,671.98
Vehicles	7,808.14
Freight Costs	1,772.97
Subcontracts	10.000.00
Indirect Costs (Overhead)	85,817.32
TOTAL	$ 457,241.69

2. Expenditures by Outputs, 7/1/76 to 9/30/77

Administration	$ 26,000
Establishment and Maintenance of Headquarters	8,500
Planning and Coordination	26,500
Project Hypothesis	
Research methodology	20,000
Field experiments	265,700
Laboratory operations	98,500
Statistical work	12,000
TOTAL	$ 457,200

Actual expenditures during the report period were lower than estimated because during the first half of this period field work did not progress at the rate anticipated. The resulting lower expenditures were mainly in the budget categories of travel, equipment, materials and supplies.

VII. Work Plan and Budget Forecast for Coming Year

A. Anticipated Accomplishments

1. Site establishment

The UPR network of experiment sites on Eutrustox will be increased by one additional site to comprise a total of six sites. In conjunction with the two Eutrustox sites established by the University of Hawaii, this will bring the total number of Eutrustox site to eight, as required for statistical reasons.

2. Transfer experiments

At each of the primary and secondary sites in Puerto Rico and Brazil, one transfer experiment with maize will be conducted during both the "dry" and "wet" seasons. Besides evaluating conventional grain yield data, the plant development will be closely monitored throughout the experiments. This can be accomplished by tissue sampling and analysis, plant height measurements at 30 days and at maturity, and periodic observations of phenological development using a system described by Hanway (1971) and Hanway and Thompson (1971) from emergence to maturity. Total stover yield and grain yield will be

determined as well as certain grain yield parameters such as ear weight and length, 100-seed weight, ears per stalk, pods per plant, etc. Although pest control measures will be administered as necessary, in the event damages do occur, visual ratings will be made as a measure of their extent.

3. Variety trials

In addition to the transfer experiments, variety trials will initially be conducted with a number of promising varieties to assure that a well adapted variety is utilized in the transfer experiments at each location. Subsequent trials including only those varieties having been selected for use in transfer experiments, will provide a better basis for the comparison of data from the various locations. In order to make an initial assessment of the varietal potential for responding to applied phosphorus, all variety trials will be of a split-plot design with two levels of phosphorus applied. Variety trials will be planted only at primary sites but will be conducted during both the "wet" and "dry" season.

Data collection from variety trials will concentrate on grain yield and other agronomic characteristics such as time to maturity, stalk lodging, and susceptibility to disease and insect attacks.

4. Management experiments

Management experiments will be designed to develop information on management practices requiring low

capital and low energy inputs. The main variables to be studied in experiments with maize and soybeans will be irrigation, tillage and fertilizers. Other commodities and practices may be added if the host country so desires.

The data of the management experiments will complement and enhance the information obtained through the transfer experiments. In conjunction with the results of fifty years of agronomic research available for the primary site at the Isabela Agricultural Experiment Station in Puerto Rico and the work conducted by EPAMIG at the site in Jaiba, Brazil, the findings of the management experiments will constitute a sizeable package of transferable technology.

Line source sprinkler experiments with maize for continuous variable irrigation-crop production studies as designed by Hanks et al, (1976) are scheduled for the next cropping season in both Brazil and Puerto Rico. The levels of applied water will range from zero to that quantity required to maintain soil moisture at or near optimum. Soil moisture will thus range from near optimal to the natural level provided by rainfall. In order to generate sufficient data to allow reliable conclusions, it is considered that at least three years of data be obtained during the "wet" season at each location. These "wet" season experiments will provide information required for making economic decisions as well as for soil

classification verification. Conducting similar experiments during the "dry" season results in more complete control of soil moisture levels, as most of the water reaching the soil will be that prescribed in the experiment design. Irrigation experimentation during that season will be designed to give more detailed information as to requirements of the crops during their various critical stages of development as well as water application schedules.

Field experiments designed to evaluate phosphorus application techniques such as banding vs. broadcasting are planned for the 1977-78 cropping seasons. Further experimentation in the areas of crop and soil management will include residual P and tillage studies and others that will depend on the results of the above experiments, problems that are seen during the conducting of transfer and variety trials, and host country interests and support.

5. Agroclimatologic Studies

The monitoring of climatologic parameters pertinent to crop production will continue as described above. The climatologic data, crop phenology observations, yields and all other parameters relevant to the development of production models or to the testing of the agrotechnology transfer hypothesis will be entered on standard data cards. The entries will be made in exactly the same manner by both the UPR and UH Benchmark Soils Projects. The accumulated data will be processed by the University of Hawaii's statistics

section upon termination of the field experimentation for the Eutrustox family.

In order to ascertain the appropriate evaluation of the climatologic parameters, an authority in agricultural meteorology will be consulted by the Project in 1978.

6. Statistics and data interpretation

Statistical tests of significance of treatment effects will be made by the UPR Agricultural Experiment Stations' Statistics Section at Rio Piedras. These tests and their interpretation will be accomplished as experiments are completed and the data become available. Running progress summaries of results will be prepared.

The basic statistical research relative to a methodology to test the transfer hypothesis conducted by the University of Kentucky under a subcontract will be continued into the extension phase. It is expected that a preliminary model will have been developed during 1978.

7. Research design

In the event that it will become evident that statistical methods alone may not suffice to conclusively prove the validity of the transferability concept, alternative pathways to substantiate the project hypothesis will be considered. For example, the configuration of the response curves for certain variables (P, K, water, etc.) should be indicative of the common response of the soils

of a given family. Other parameters that may be useful to support the project concept include the nature of the P-isotherm curves, moisture storage and release properties, root development as a function of depth, and other characteristics related to the soil family.

8. Dissemination

The planning and organization of an international seminar to disseminate Project principles and results among soil scientists and land use planners of Latin America will be initiated. Tentatively, this seminar is entitled "Agrotechnology Transfer via Soil Classification" and will be held at a yet undetermined location in Latin America in 1979.

Jointly with the University of Hawaii, the "Benchmark Soils Quarterly" will be published and distributed in tropical America. A comprehensive report on the Benchmark Soils Projects will be prepared together with the University of Hawaii and circulated widely in the tropical world.

10. Critical assumptions

Various circumstances beyond the control of the contractor may impede accomplishments. An assumption of critical importance is that the kind of soils meeting the taxonomic requirements for inclusion in the network occur in locations where experimentation is logistically possible and where suitable arrangements can be negotiated with the host country.

The present Project Leader in Brazil will leave the Project at the end of this year to pursue PhD. studies. It is obviously critical that a qualified replacement can be identified and appointed in due time. In view of the professional, administrative and linguistic requirements of the position, the very remote location of the experiment sites in Brazil, and other excellent job opportunities in international agriculture, it will be difficult to find a suitable person.

B. Budget Forecast

Estimated Expenditures, 10/1/77 to 9/30/78	
Salaries & Wages	$ 168,700
Consulting Fees	3,200
Fringe Benefits	28,700
Travel & Per Diem	40,800
Equipment	43,300
Materials, Supplies & Services	59,200
Vehicles	3,800
Freight Costs	6,600
Publication Costs	2,700
Indirect Costs (Overhead)	87,600
TOTAL	$ 444,600

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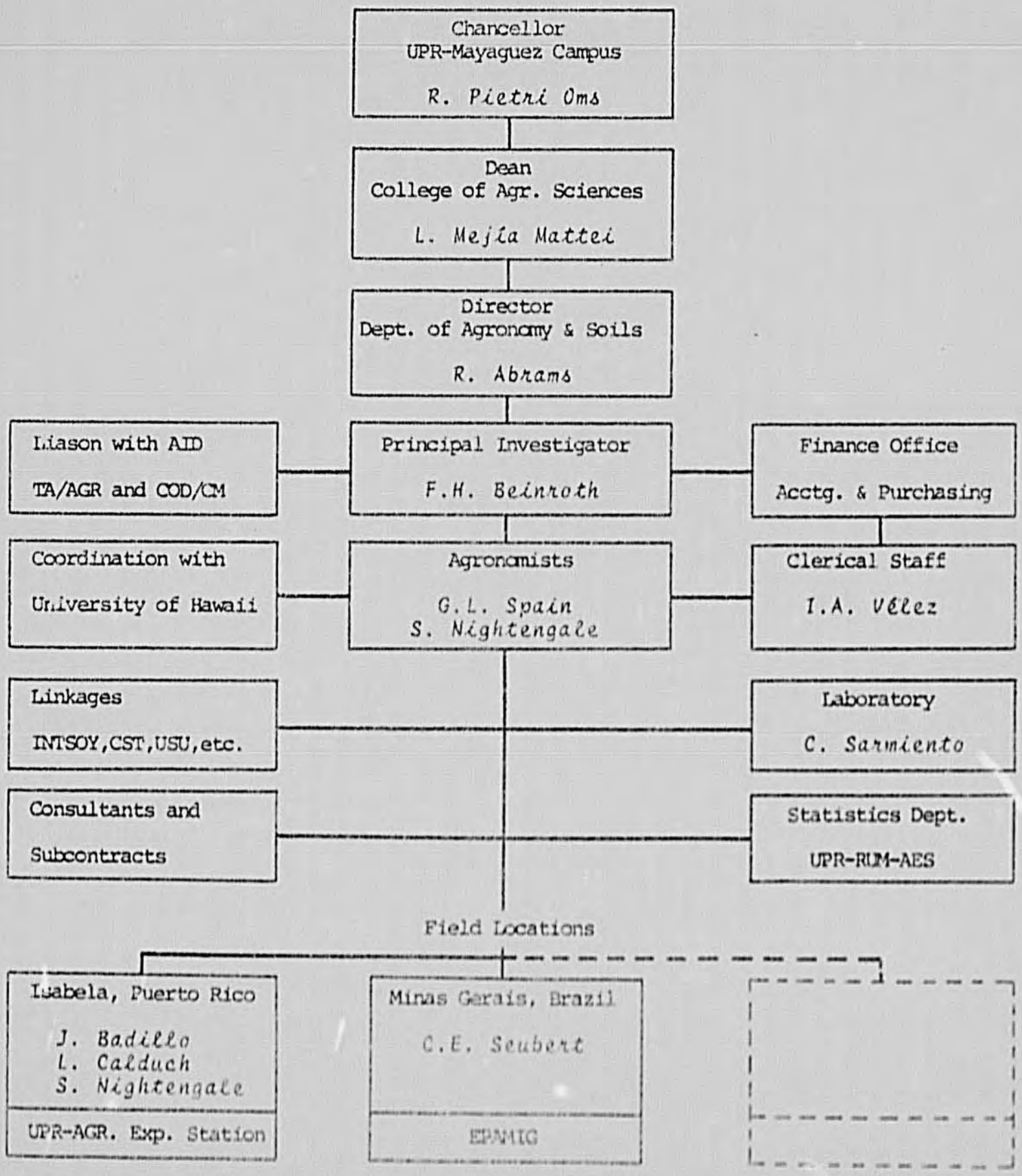
Appendix A1

University of Puerto Rico - Benchmark Soils Project

ORGANIZATION CHART



Appendix A2

Personnel Employed by Benchmark Soils Project

Name	Title	Project Position Responsibilities
Home Office Professional		
F. H. Beinroth, Ph. D.	Professor	Principal Investigator Administration and fiscal management of Project, liaison with AID/W, Univ. of Hawaii and cooperators; pedologic aspects and site selection
G. L. Spain, Ph. D.	Assoc. Professor	Senior Agronomist Planning, design and organization of field experiments; coordination and supervision of field work in the UPR network; coordination with Univ. of Hawaii; data organization and processing
L. C. Sarmiento, MS.	Ass't. Professor	Chemist In charge of analytical laboratory, soil and plant analyses
L. Costa Mayoral, BS.	Research Ass't.	Research Assistant Soil and plant analyses
J. A. Vega López, BS.	Research Ass't.	Research Assistant Soil physical analyses
Home Office Nonprofessional		
I. A. Vélez	Secretary	Secretary Clerical work, typing and accounting
- - - - -	Grad. Students	Student help Routine laboratory assistance

Field Staff Professional

J. Badillo, Ph.D.	Assoc. Agronomist	Project Leader, Isabela Sites Conduct and supervision of field experiments
S. P. Nightengale, MS.	Ass't. Agronomist	Ass't. Project Leader, Isabela Sites Conduct and supervision of field experiments, data organization and processing, liaison with Senior Agronomist
L. Calduch, BS.	Research Ass't.	Research Assistant, Isabela Sites Conducting field experiments, supervision of laborers, data collection
C. E. Seubert, M. S.	Ass't. Agronomist	Project Leader, Brazil Sites Planning, design and conduct of all experiments in Brazil; administration of Brazil operations; liaison with EPAMIG

Field Staff Nonprofessional

F. Mercado Badillo	Research Aide	Field Aide, Isabela Sites Assistance in all phases of field work; maintenance of experiments
N. de Sa	Research Aide	Field Aide, Jaiba Sites, Brazil Assistance in all phases of field work; maintenance of experiments
M. A. Caldeira Torres	Research Aide	Field Aide, Jaiba Sites, Brazil (ditto)
- - - -	Laborers	Field Laborers, Isabela and Brazil Sites

Appendix B

Table 1. Treatment Combinations for Transfer Experiments with Maize

High Base Status Soils

Treatment	Coded Levels 1/ P	Coded Levels 1/ N	Actual Levels 2/ P in Sol'n ppm	Actual Levels 2/ N Applied kg/ha
A	-0.85	-0.85	.001	14
B	-0.85	+0.85	.001	167
C	+0.85	-0.85	.013	14
D	+0.85	+0.85	.013	167
E	-0.40	-0.40	.004	54
F	-0.40	+0.40	.004	126
G	+0.40	-0.40	.010	54
H	+0.40	+0.40	.010	126
J	"Optimum"	"Optimum"	.007	90
K	-0.85	"Optimum"	.001	90
L	+0.85	"Optimum"	.013	90
M	"Optimum"	-0.85	.007	14
N	"Optimum"	+0.85	.007	167
O	Partial control, blanket application only			
P	No applied P, "optimum" N, blanket application			
Q	"Optimum" P, no applied N, blanket application			

Blanket application for all plots:

Element	kg/ha	Source
K	125	KCl
Mg	100	$MgSO_4 \cdot 7H_2O$
Zn	15	$ZnSO_4 \cdot 7H_2O$
B	2	Borax

1/ Coded levels are based on "optimum" levels. The assumed "optimum" levels of P in solution for maize is .007 ppm and the "optimum" level of N is assumed to be 90 kg/ha. Other treatment levels are "optimum" levels plus or minus 0.40 or 0.85 x "optimum" levels.

2/ "Actual" levels of P are determined by the phosphorus sorption isotherm technique (Fox and Kamprath, 1970).

Appendix B

Table 2. Maize transfer experiment planted April 2 and harvested August 6, 1976 at Isabela, Puerto Rico primary site, variety Pioneer 306 B.

Grain Yield[1/] kg/ha

.09	10375		11080		9750
.07		11287		11441	
.05	11515		10560		11134
.03		10377		11112	
.01	9401		10565		9843
	19	75	125	175	231

K kg/ha

Complete control 6530
Partial control 8526

Table 3. Maize transfer experiment planted August 2 and harvested November 16, 1976 at Isabela, Puerto Rico, secondary site, variety Pioneer 306 B.

Grain Yield[1/] kg/ha

.09	6028		6365		6114
.07		6259		5801	
.05	6414		5806		6240
.03		5967		6260	
.01	5907		5501		6402
	19	75	125	175	231

K kg/ha

Complete control 3651
Partial control 3694

1/ Adjusted to 15.5% moisture.

Appendix B

Table 4. Maize transfer experiment planted December 13, 1976 and harvested April 18, 1977 at Isabela, Puerto Rico, secondary site, variety Pioneer 306 B.

Grain Yield[1/]
kg/ha

P ppm	19	75	125	175	231
.09	5772		6092		6411
.07		6400		7070	
.05	5912		6138		6605
.03		6758		6364	
.01	5874		5118		6410

K kg/ha

Complete control 4165
Partial control 5208

Table 5. Maize transfer experiment planted December 22, 1976 and harvested April 26, 1977 at Isabela, Puerto Rico, primary site, variety Pioneer 306 B.

Grain Yield[1/]
kg/ha

P ppm	19	75	125	175	231
.09	8004		7085		7302
.07		7517		6984	
.05	7408		8557		8470
.03		8082		7607	
.01	8161		6134		8257

K kg/ha

Complete control 6727
Partial control 6337

1/ Adjusted to 15.5% moisture.

Appendix 6.

Table 6. Maize transfer experiment planted October , 1976 and harvested March , 1977 at Jaiba, MG, Brazil, primary site, variety Phoenix 1110.

Grain Yield 1/
kg/ha

P ppm	19	60	100	140	185
.09	8545		7433		7748
.07		7588		7714	
.05	6778		8772		7748
.03		7584		7952	
.01	6874		6600		8142

K kg/ha

Complete control 1141
Partial control 1293

1/ Adjusted to 15.5% moisture.

Appendix B

Table 7. Soybean transfer experiment planted March 5 and harvested August 3, 1976 at Isabela, Puerto Rico, primary site, variety Jupiter.

Grain Yield[1/]
kg/ha

P ppm	19	75	125	175	231
.19	918		722		865
.14		945		756	
.10	1019		1024		887
.06		1132		954	
.02	1375		928		734

K kg/ha

Complete control 996
Partial control 935

Table 8. Soybean transfer experiment planted July 30 and harvested November 29, 1976 at Isabela, Puerto Rico, secondary site, variety Bardee 63

Grain Yield[1/]
kg/ha

P ppm	19	75	125	175	231
.09	2628		2813		2836
.07		2927		2804	
.05	2873		2606		2792
.02		2804		2673	
.01	2551		2441		2481

K kg/ha

Complete control 2867
Partial control 2421

1/ Adjusted to 15.5% moisture.

Appendix B

Table 9. Soybean transfer experiment planted December 9, 1976 at Isabela, Puerto Rico, secondary site, variety Hardee LS.

Grain Yield, kg/ha[1/]

P ppm	19	75	125	175	231
.19	1637		1637		1324
.14		1579		1451	
.10	1667		1559		1528
.06		1721		1499	
.02	1311		1399		1194

K kg/ha

Complete control 1159
Partial control 1037

Table 10. Soybean transfer experiment planted December 21, 1976 at Isabela, Puerto Rico, primary site, variety Hardee LS.

Grain Yield, kg/ha[1/]

P ppm	19	75	125	175	231
.19	1765		1862		1833
.14		2155		2010	
.10	1626		2054		1927
.06		1944		1742	
.02	1546		1645		1996

K, kg/ha

Complete control 1508
Partial control 1287

1/ Adjusted to 15.5% moisture.

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Table 14. Soil moisture level at the time of the first plowing operation and its effect on soil aggregate size, soybean stand and grain yield. The data are means of four replications. UPR Benchmark Soils Project

Soil Moisture %	Aggregates 1-25 mm %	Plants/Plot No.	Grain Yield kg/ha
25.72	43.07 b 3/	22.75 c	332.6 c
24.63	45.82 b	32.70 c	577.5 b
24.08	47.50 b	41.25 bc	624.3 b
23.62	53.38 ab	43.50 bc	668.2 b
21.10	62.02 a	73.50 a	911.3 a
20.82	68.86 a	66.50 ab	769.8 ab

1/ Percentage of intermediate (desirable) sized soil aggregates, 1 to 25 mm diameter, in the prepared seedbed at planting.

2/ Number of plants per plot 25 days after planting.

3/ Means not followed by common letters are significantly different at the 0.05 level of probability of error.

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Table 12. Maize yield and plant lodging data from a variety x phosphorus level trial planted May 14, 1976 at Isabela, Puerto Rico and harvested August 30. All values are means of three replications over two phosphorus levels.

Variety	Grain Yield kg/ha*		Lodged Plants count*	
Pioneer 304C	9782	a	0.7	
Pioneer 304B	8957	ab	4.3	e
Pioneer 304A	8349	bc	9.3	bcde
Hawaii H638	8314	bc	9.7	bcde
Pioneer 105A	8186	bcd	8.8	bcde
Hawaii H652	8019	bcd	7.5	bcde
Pioneer 306B	7687	cde	11.3	abcde
Hawaii H788	7659	cde	13.2	ab
UPCA-1, Phil.	7238	cdef	4.3	e
Hawaii H610	7094	def	5.2	de
TNIA H507, Mex.	7058	def	12.3	abc
Honduras H5	7028	def	17.5	a
Diente de Caballo, P.R.	6966	def	11.2	abcde
Mayorbela, P.R.	6673	ef	5.5	cde
DMR, Phil.	6402	f	5.3	de
Oaxaca 179, Mex.	4670		5.7	cde

*Values not followed by common letters are different at the 5% level.

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Table 15. Top varieties of the Brazilian National Maize Variety Trial Planted 30 Oct 76 - Jaíba, Brazil. UPR Benchmark Soils Project.

VARIETY	GRAIN YIELD 1/	
	kg/ha	bu/A
Pioneer X304 B	7740	122
Pioneer X304 A	7680	121
Pioneer X304 C	7457	117
Pioneer X306 B	7442	117
Contibrasil 3	7380	116
Cargill 318	7222	113
Cargill 111	7217	113
Cargill 111 X	7145	112
Cargill 111 S	7127	112
Cargill 317	7105	112
Cargill 5005 M	7035	110
Pioneer X105 A	7033	110

1/ Adjusted to 15.5% moisture

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Table 16. Maize Variety x P Level Trial Planted 26 Oct 76 - Jaiba, Brazil, UPR Benchmark Soils Project.

VARIETY	GRAIN YIELD (kg/ha)[1/] P level, ppm P in soil solution			
	Natural	.025	.050	.075
IAC Phoenix 1110	3444	8420	7634	8824
Agroceres 259	3661	8736	8725	8938
Cargill 111	4346	9068	9880	9099
Maya X	4110	7830	9357	9062
Pioneer X306 B	4036	7761	8406	8652
$\bar{x}$ Varieties	3920	8363	8800	8961

1/ Adjusted to 15.5% moisture.

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Table 17. Top Varieties of the INTSOY Soybean Variety Trial Planted 25 Nov 76 - Jaíba, Brazil, UPR Benchmark Soils Project.

VARIETY	GRAIN YIELD 1/	
	kg/ha	bu/A
Davis	4479	70
Bragg	4002	63
Ransom	3815	60
Bossier	3512	55
Forrest	3475	55
Columbus	3397	53
Clark 63	3261	51

1/ Adjusted to 15.5% moisture.

Appendix B

Table 18

Maize Variety x Density x Spacing Experiment
Planted 28 Oct 76 - Jaíba, Brazil
UPR Benchmark Soils Project

Cateto Colombia
kg/ha[1]

Population (plants/ha)	50	75	100
60,000	5612 (33)[2]	4783 (22)	4596 (17)
40,000	5203 (50)	5003 (33)	4038 (25)
20,000	3805 (100)	4119 (67)	-- (50)

Distance between rows
(cm)

Piranão
kg/ha

Population (plants/ha)	50	75	100
60,000	6955 (33)[2]	7015 (22)	6201 (17)
40,000	6341 (50)	6631 (33)	6873 (25)
20,000	4457 (100)	5604 (67)	-- (50)

Distance between rows
(cm)

1/ Adjusted to 15.5% moisture

2/ Indicated plant population were obtained by planting at in-row spacing shown in parentheses for each between-row distance.

Appendix C

Bibliographical List and Abstracts

Some considerations on Soil Classification in general and Soil Taxonomy in particular. F.H. Beinroth. Proc. Workshop on Experimental Designs. Univ. of Hawaii (In press).

The basic rationales of soil classification and the kinds of classification system and their purposes are discussed. The new U.S. system of soil classification, Soil Taxonomy, is elucidated with particular emphasis on the system's dependence on the state of knowledge, its genetic bias and its inherent limitations for agricultural interpretations. The applicability of Soil Taxonomy in the process of agrotechnology transfers in the tropics is examined.

Considerations on Experiment Designs and Production Functions. B.G. Capó. Proc. Workshop on Experimental Designs. Univ. of Hawaii (In press).

The author details some of the production functions advanced to date. It is argued that none of these equations provides for a point of inflexion in the yield curve at relatively low levels of a yield controling factor, nor for the point of inflexion which exists at relatively high levels of such a factor. A novel, multiplicative production function is proposed and its validity is demonstrated.

Economic Aspects of Production Functions for Soils. G.E. Pringle. Proc. Workshop on Experimental Designs. Univ. of Hawaii (In press).

The use of production functions in agricultural economics is described. The desirable attributes of production functions are enumerated and experimental design considerations for attaining appropriate data for economic analysis are discussed. The application of the Capó function to a fertilizer experiment conducted in Puerto Rico is demonstrated and some economic aspects of this equation are discussed.

Report of the Workshop on Experimental Designs for Predicting Crop Productivity with Environmental and Economic Inputs. J.A. Silva and F.H. Beinroth. 1975. Univ. Hawaii Agr. Exp. Sta., Departmental Paper 26

This report summarizes the papers presented at the Workshop and includes a position paper on field experimentation to allow economic evaluation of management and environmental effects on soil productivity. The report further contains the recommendations which transpired at the workshop.

Soil Classification and the Transfer of Agrotechnology. F.H. Beinroth. Paper prepared for AID Soil and Water Management Workshop, Washington, D.C. 1975.

Peculiarities of the transfer of agrotechnology to LDCs, as opposed to technology transfer in the industrial sector, are discussed. The potential value and utilization of soil classification in the process of agroproduction transfer in the tropics is elucidated. The rationale of the Benchmark Soils Project and the research strategy are explained.

Soil Classification and the Transfer of Soil Management Experience. F.H. Beinroth and G.L. Spain. Proceedings Fifth Latin American Congress of Soil Science, Medellin, Colombia (In press).

The paper describes the rationales and objectives of the Benchmark Soils Project. A hypothesis is advanced relative to the transfer of agroproduction technology on the basis of soil families as defined in the U.S. Soil Taxonomy. A research strategy to test the validity of this concept involving agronomic experimentation in various countries is explained. The objectives of the study and its implications for agricultural development in the tropics are described.

Some Fundamentals of Soil Classification. F.H. Beinroth 1976. Proceedings Seminar on Uses of Soil Survey and Classification in Planning and Implementing Agricultural Development in the Tropics, ICRISAT. Hyderabad, India (In press).

Taxonomic soil classifications are conceptual frameworks showing the relationships inherent in the population of soils and allowing comparisons of soils for both similarities and differences. The principal practical application of soil classification is in soil surveys. These can be interpreted for a variety of technical uses, including the transfer of agrotechnology. Taxonomic systems such as the U.S. Soil Taxonomy with a large number of precisely defined taxa in the lower categories are best suited for this purpose. Soil survey interpretations for crop production provide qualitative groupings and do not circumvent the need for specific agronomic soil testing.

The Benchmark Soils Projects, an innovative approach to agrotechnology transfer. L.D. Swindale, J.A. Silva and F.H. Beinroth. Paper presented at CLAMATROPS Conference, Kuala Lumpur, Malaysia, 1977

The paper describes the Benchmark Soils Projects and reports accomplishments and preliminary results. It also indicates how, by an extension of project work, it should be possible to establish a network of soil research station throughout the tropics, and how the concepts of the projects can be used for agrotechnology transfers.