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9. ABSTRACT

A project to determine the extent to which agricultural technology developed under high levels of management in tropical regions (Hawaii, for example) can be transformed to developing countries whose crop yields are low. This effort is based on the knowledge that with proper technology yields can often be doubled or tripled without soil deterioration. This project does not assume that technology transfer can be made in a single step. Rather, it plans to apply modern technology to soils similar to those in Hawaii or Puerto Rico. Selection will include some countries in Africa, Southern and Eastern Asia and Latin America. Probable crops: corn, upland rice or sorghum, yams or cassava. Objective: to develop applications of technology suitable to local soils and to establish crop yield bench marks which local governments can use in demonstrations and other socio-economic means for introducing improved methods to the local population.

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CROP PRODUCTION AND LAND CAPABILITIES OF A NETWORK OF TROPICAL SOIL FAMILIES-- A DESCRIPTION OF THE UH/UPR/AID BENCHMARK SOILS RESEARCH PROJECTS

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INTRODUCTION

From most authoritative sources in recent years it has been firmly stated that major emphasis must be given to increasing productivity per unit of land if the world food needs are to be met. Through research and extension, the temperate regions of the world have achieved high productivity in agriculture. The Green Revolutions in wheat and rice in Mexico, India, Pakistan, and the rice bowls of Asia give clear indication that such advances are also possible in the tropics. What is most needed is a clear indication of the regions in tropical countries where it is possible to concentrate immediate food production efforts. Throughout tropical Asia, Africa and Latin America, crop yields on the upland soils that will be the focus of this experiment are very low. Existing national knowledge, therefore, is no guide to the true potential of these soils. Thus, if it can be shown that profitable crop yields can result--yields two or three times greater than are presently thought possible--without consequent soil deterioration, a modern agricultural system can be developed without the necessity of 50 years of experimentation and extension.

The high yields resulting from extensive soil management in Hawaii on

tropical soils are based upon current practice in relation to sugar, coffee, sorghum, fruits, vegetables and tuber crop production, and upon 70 years of continuous agricultural research by the H.A.E.S. and the research stations of the sugarcane and pineapple industries. We need to find ways to transfer these results to other tropical regions. The purposes of these projects are to correlate food crop yields on a network of benchmark tropical soils, and to determine scientifically the transferability of agroproduction technology among tropical countries, and particularly from Hawaii and Puerto Rico to tropical developing countries.

The projects are central to the need for improved information on the management of tropical soils and water, a major current interest of the Agency for International Development. For the most part, temperate countries have made great progress in developing their soil resources. But the majority of the world's underprivileged people live in the tropics, and the soils of the tropics have so far proved difficult for most people to manage.

The magnitude of the problems of managing tropical soils was documented by the UN Conference on the Application of Science and Technology for the Benefit of the Less-Developed Areas(Vol. 3, Chap. 2, Geneva, 1963). More recently Aubert and Tavernier in Soils of the Humid Tropics (1972), a review undertaken by the National Research Council for AID, concluded: "In equatorial regions...basic agricultural experimental work is lacking for adequately predicting soils behavior."

Only when countries in the tropics have gained an appreciation of the potential of their soils under different levels of management will it be possible for them to plan both (a) to insure basic food and protein supplies and (b) to promote the production of exportable crops. But at present, in most tropical countries, research efforts related to basic food and protein

supplies are aimed at a low level of soil management with consequent high food prices and occasional food shortages. Under these conditions, lacking the information and perspective necessary, it is not possible to create the progressive rural structure and the modern agriculture that Mosher (1969) proposed in Creating a Rural Progressive Structure (Agricultural Development Council, N.Y.).

The benchmark soils that are to be the bases of the research network will belong to related soil families as defined by the new U.S. Soil Taxonomy. This Taxonomy, essentially completed in 1971, has as its major purpose the establishment of relationships among soils and between soils and their natural and cultural environments. Through proper use of the classification, predictions can be made about soil behavior from the relations of soils for which we lack experience, to soils on which we have conducted research or have experience.

This system of soil taxonomy has been developed over the last 22 years by the Soil Conservation Service of the USDA with active cooperation of the Land-Grant Colleges and soil scientists in foreign countries. It is by far the most comprehensive, precise and most nearly logical system of soil classification yet developed.

The fifth level of subdivision in the system is the soil family. Dr. Charles E. Kellogg, while Deputy Administrator for Soil Survey of the Soil Conservation Service, described the significance of soil families (Kellogg, 1964). He pointed out that many characteristics that can be related to plant growth and to engineering were related to the soil family subdivisions, and, in consequence, the soil family provides the link between soil classification and land capability groupings. Soils in the same family should have essentially the same management practices. Therefore, it is

essential to classify soils in different lands into their common families in order to make reasonably direct transfers of agricultural know-how, or, conversely, when soils have been classified into their common families, it should be possible to use the maximum production results of one soil as production targets for all soils in the same family.

Existing knowledge about the use of the soil family for technology transfer has been established in the continental United States and in Hawaii through cooperative work of the Soil Conservation Service of the USDA and the State Agricultural Experiment Station. De Ment, et al. (1971), critically examined the family classification system to see how well it has worked within the continental United States. In the abstract of their report they state, "In general, crop suitability correlates well within classes at the family level. Yields for short-season crops can be reliably predicted, particularly if soil slope and erosion phases are used. Yield predictions are less reliable for long-season crops that are subjected to moisture stress during parts of the growing-season." The authors suggest that some classes of soil moisture stress during the growing season should be used in family criteria.

Experience has shown that agricultural technology developed for temperate zone soils is not directly transferable to the tropics. But evidence has not yet been obtained to determine the extent to which agricultural technology developed under high levels of management in tropical regions can be transferred. Recent progress in soil classification related to questions of transfer of technology and research in Hawaii give considerable hope that this can be done.

For example, for short season crops, yields and cost of production of head cabbage and lettuce on the Kula and Waimea soil series, two soils in

the medial isothermic family of Typic Eustrandepts on different islands of the Hawaiian chain are very similar. For longer season crops, yields of sugarcane, pineapple, papaya, and pasture production on soils in the same family are listed as being equal by the SCS in their forthcoming reports on the soils of the State of Hawaii.

The success of the soil taxonomy system at the family level in many U.S. soils and within the limited testing that has been possible in tropical and subtropical Hawaii suggests that it can be used to transfer agricultural technology between soils in many tropical regions. Thus, the present high-level of agricultural technology developed in Hawaii for crops such as sugar (0.53 tons sugar per acre per month), pineapple (3T/A/Mo), papaya (2.5T/A/Mo), sorghum dry grain (1.0T/A/Mo), maize dry grain (1.1T/A/Mo) and beef production (83 lb/A/Mo) can be translated to the less-developed countries.

In making this assertion it is fully realized that the translation can only be made initially in terms of production targets. Many problems, social and economic as well as technical, will need to be solved before production targets become production realities. But this correspondence of soils will show what soils should be developed first, what comparative advantages exist, and what direction the countries should take in their development plans. It may also determine on what soils in Hawaii and Puerto Rico future research should be concentrated to provide the greatest benefit for the less-developed countries.

Although soil families have not yet been fully classified in tropical Asia, Africa or America, soil survey and characterization has progressed far enough in the countries indicated as possible participants that the selection of benchmark soils in soil families common with Hawaii and Puerto Rico should not be too difficult. One example of transference of Hawaii

soil management practices based on soil classification criteria, is response of sugarcane to soluble silicates in Humic Ferruginous Latosols in Mauritius following the earlier response to silicates on these soils in Hawaii (Plunkett, 1972).

The most likely countries in which the right soils will be found are Ethiopia, Zaire, Tanzania or Kenya in Africa; Sri Lanka, Indonesia, India (Kerala or Mysore), the Philippines (Mindanao) or Vietnam (the Central Highlands) in Asia; and Colombia, Peru, Venezuela or Brazil in Latin America.

Two crops will be grown at each station in the network in a series of linked-parallel experiments. The most probable crops will be a cereal, either corn, upland rice or sorghum, and a root crop, either cassava or yam. Yields and other output criteria will be correlated among the stations and in relation to land potentials and capabilities in the countries of the network.

The projects will establish by their findings the factors that must be taken into account in order to make the soil family level work in the tropics as it does in the temperate zone, as the classification level to be used in the transfer of agricultural knowledge from place to place.

In later phases of the projects and in concert with related AID research contracts and with national and international research institutions, the research network of benchmark soils will be extended to other areas in the above countries and to other countries in the tropical regions of the world. Because the crops used in the experiments will be of local importance --but probably of improved genetic stock--government agencies will be able to use the experiments for demonstration purposes in local development and to prepare for the creation of local village organizational structures to maintain long-term benefits from the work carried out.

SPECIFIC OBJECTIVES

1. University of Hawaii Project
   a. To correlate crop yields to land potential and capability on a network of upland tropical soils.
   b. To establish by experimentation and demonstration the transferability of agricultural technology between Hawaii and other tropical regions and among those regions.
2. University of Puerto Rico
   a. To correlate crop yield to soil parameters on a network of red upland soils of the tropics.
   b. To establish by experimentation the transferability of agricultural technology among tropical countries.
   c. To demonstrate the agricultural potential of tropical red upland soils in LDCs of Latin America.

DESIGN OF EXPERIMENTS

1. Selection of Soils

A comparative study of soil and climatic maps at scales around 1:5,000,000 will be used to delineate probable areas of interest. The resources of the Universities' holdings on tropical soils, the AID (211-d) Consortium on Tropical Soils, the World Soil Geography Unit of the USDA, and the FAO/UNESCO Soil Map of the World will be used to provide the information needed.

Detailed soil investigations will need to be conducted in the field to obtain the information necessary to classify soils and to determine if the soil areas meet the criteria that will be used to determine their suitability

for linked-parallel experiments on crop production.

Hawaii and Puerto Rico have one family of Tropeptic Eutrorthox and one family of Orthoxic Tropohumults in common. When these families occur in other regions they will be used. Otherwise other closely related soils will be used which have families in two or more of the locations of the network. In general, it is expected that the work will be concentrated in families of Andepts and Oxisols which are well represented and used for intensive agriculture in Hawaii.

2. Crop and Soil Management Experiments

The experimental designs to be used will be in part determined by the results of this workshop.

The objectives of the experiments will be:

a. To determine the potential productivity of soils under high management input.

b. To develop optimum management systems for multiple cropping.

c. To determine optimum plant population for various crops under local soil and climatic conditions.

The potential productivity of soils at each location will be determined with an N x P x K experiment to allow correlation with soil parameters and evaluation of transferability of agricultural technology. The aim is to attain maximum or near-maximum production with appropriate levels of these nutrients under optimum management conditions, i.e., adequate irrigation, calcium (pH), plant protection (weed, disease and insect control), and plant population.

3. Land Capabilities

The soils data, soil characteristics, yield data and related climatological data will be processed by methods of multivariate analysis to produce the desired land potential, capabilities and transferability information. Local yield data and land capability information where it exists will probably be included in the data base to increase the chances of making yield predictions at various levels of the soil classification to cover a larger group of soils than will be represented by the benchmark soil network.

Where similar soil indexes of production capabilities are determined by analysis, the information will be directly translated through the soil linkage as a first approximation to production targets for these soils where they occur in other tropical and subtropical lands.

CONTRIBUTIONS TO INSTITUTION BUILDING

The projects are proposing a creative approach to the development of modern agriculture in tropical countries. They will need to work closely with national research institutions to change in part their orientation and targets and retrain some of their staff, depending upon where the stations are established. The projects propose to work through the strengths of national institutions. Included in the proposals are funds enough to provide fellowships for staff members of these institutions to undertake training courses and graduate degree courses at the two Universities.

The seminars, workshops and meetings that will be part of these projects will also contribute to training institutional counterparts and national field staff of the project.

The projects will give participating countries a basis for understanding

and exploring the potential of their soils for crop production. They should lead to increased soil-based research in national institutions as they seek similar information for soil families not included in the project studies.

The two Universities will be strengthened by the project. Their staffs will gain a greater insight into the problems of tropical countries and will gain in knowledge and understanding through their contacts with other research scientists. Their store of research information will be increased by the experiments conducted.

The authors of The Soil Taxonomy of the USDA recognize its probable inadequacies in the classification of tropical soils. Referring to the Oxisols, soils central to the objectives of this project, the Taxonomy states, "The classification of Oxisols...seems to produce satisfactory groupings of the...soils in Hawaii and Puerto Rico. It needs to be tested more widely... and is far from completion." Soil scientists in tropical countries have recognized the value of the Taxonomy by using it to the extent that their limited analytical data will allow. The U.S. Soil Conservation Service and the use of the Soil Taxonomy in tropical countries should benefit substantially from the findings of this project.

DISSEMINATION AND APPLICATION OF THE RESULTS

It is expected that the projects will demonstrate that the transition from traditional to modern intensive agriculture can be made efficiently and with a minimum of error by means of technology transfer from the developed to the less developed regions of the tropics. It should also show that management systems implemented in one soil in one region can be transferred to the same soil in any other region.

This transferability of existing agricultural knowledge will be demonstrated on an international network of benchmark soils families. Preliminary results will also demonstrate transferability of knowledge for several in-country sites related to the international network.

The land capability schemes developed for the countries of the network should be able to indicate suitabilities of different regions for development under high, medium, or low levels of input and the probabilities for the success of information transfer from the network. This information will be available for incorporation into the 5-year development plans of the cooperating nations, and the project personnel will work to involve national planners in the project from its early stages, and include them in the training seminars and workshops.

Corn, sorghum or upland rice and cassava or yam will be cultivated continuously for three years. Two years of data will be obtained on other crops. Yields from the experimental plots are likely to be two to six times greater than those obtained by farmers cultivating similar soils and using traditional agricultural practices.

Bird and rodent damage in addition to disease, insect and weed infestation, will seriously limit yields in the control plot. The projects will therefore have strong visual impact and will also supply scientific data related to locally important crops.

Strict management control of the projects will be required in order to obtain highly profitable yields in upland areas. It is hoped that AID Missions and local and national institutions will assist in organizing farmer field days and other local training sessions that will be associated with the project. Governmental willingness to support farmers who have been psychologically prepared to make the change will be necessary in order to ensure basic

food supplies.

Fellowships will be offered to students from host countries with leadership potential. They will receive academic training at the Universities and field experience on the experimental site in their home country. Those students working on thesis research in their home countries can help local farmers incorporate the newer methods into their social and cultural framework.

Training seminars for the project staff will be held in years 1,2,4 and 5. These will provide training on soil families and classification, experimental design and crop management, and on interpretation of the project results by the staff. Project workshops will also be held to acquaint appropriate officials of cooperating countries and AID staff members with the purposes and benefits of the project, and the meaning of the results as they are obtained. These workshops will also be used to obtain important input into the project from individuals and to maintain their involvement to a high degree.

RELATION TO INDIGENOUS AND INTERNATIONAL INSTITUTIONS

When the stations of the network have been decided upon, arrangements will be made with indigenous institutions to assist and advise the projects. The willingness of such institutions to play such a role will be an important criteria in determining where stations will be.

The projects will draw directly on past and current research on crop and soil management by the Hawaii and Puerto Rico Agricultural Experiment Stations. It should be able to draw also on the expertise of the AID/University (211-d) Consortium on Tropical Soils, which includes Cornell University, North Carolina State University, Prairie View Agricultural and Mechanical University, and the

Universities of Hawaii and Puerto Rico.

For suitable crop varieties the project will cooperate with IRRI, ITTA, WARDA, CIMMYT, IFAT, and other research institutions that can provide the required information. For assistance in soil selection the project will cooperate with national soil survey institutions, the Soil Conservation Service of the USDA, ORSTOM, INEAC, and FAO.

Cooperative arrangements with other AID-sponsored projects working in similar regions or similar fields, is expected to be achieved through AID. We are hopeful that the AID-sponsored research by Cornell and North Carolina State that deals with soil fertility assessments and crop production in Latin America will help us with advice and information, and perhaps set up cooperative experiments on suitable benchmark soils in their regions of work.

The work in Africa will be closely coordinated with IITA which has on its staff several individuals who have worked in H.A.E.S. and obtained graduate training in the College of Tropical Agriculture of the University of Hawaii. The soil management program and orientation of IITA can be extended to other areas of Africa through such coordination.

Belgian scientists at INEAC and the Universities of Louvvain and Ghent, who have had considerable experience with soils of the type to be included in this project are also being consulted and included as cooperators when suitable arrangements can be made.

It is to be expected that the work in Asia will be coordinated with the new crop management extension program of the International Rice Research Institute. A proposal has recently been developed and has been approved in principle to conduct a major seminar on the relevance of modern soil and land classifications to the development of tropical soils with joint sponsorship by the Hawaii project and ICRISAT. The seminar would be held at ICRISAT in

December 1975.

The work in Latin America will be coordinated with CIAT, CIMMYT and ICCA through the University of Puerto Rico.

FUTURE PLANS

Data for additional crops will be obtained at the stations of the research network. New stations on additional soil families will be established in the countries of the network to extend the usefulness of the results and test the validity of the land capability schemes more adequately.

First priority for extension of the projects to new locations will be given to regions with high agricultural potential in which a breakdown of the traditional agricultural system appears imminent. The transfer of technology will be linked to a strong farmer training program. The host country in turn must give assurance that a permanent support program which gives farmers access to fertilizer, chemicals and seeds will be established. Transfer of agrotechnology is only a necessary first step in agricultural development.

Second priority should be given to sparsely populated regions with high potential for development. Between the humid and arid regions there is a large segment of the tropics in which continuous cropping is restricted by low rainfall during three to six months of the year. Introduction of agrotechnology to these areas will give government planners the information which is needed to plan for water resource development and proper use of the soil resources.

Thirdly, the transferability of technology should be tested in regions of medium to low potential, where shifting agriculture will continue to be

practiced for many more generations. Introduction of agrotechnology to these areas will serve as a means to prepare the people for exposure to the outside world.

The projects, therefore, should have both visual impact in and technical value to the participating countries.

The experience and knowledge gained from this project will:

1. remain in the host country to create a progressive rural structure, and
2. be extended to other tropical regions with immediate and future growth potential.

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