

CARIBBEAN COMMISSION  
CENTRAL SECRETARIAT

SOIL  
SCIENCE  
IN THE  
CARIBBEAN

Report of the Soils Conference held in  
Puerto Rico, March 30—April 8, 1950

KENT HOUSE  
PORT OF SPAIN TRINIDAD  
1950

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## FOREWORD

The report of the Soils Conference, held in Puerto Rico from March 31 to April 8, 1950, under the joint auspices of the Caribbean Commission and the Agricultural Experiment Station of the University of Puerto Rico, is not only of intrinsic value; it also has special significance for the forthcoming West Indian Conference (Fourth Session) in Curacao in November of this year, the theme of which is "The Agricultural Problems of the Caribbean Area".

The Central Secretariat of the Commission takes this opportunity of expressing its warmest appreciation of the collaboration of the territorial governments in presenting the detailed statements, included in this publication, of the existing state of knowledge, problems and needs with respect to soil science in their respective territories.

The Caribbean Commission has assigned to the Secretariat as one of its continuing activities the preparation and publication of bibliographies in the various fields of inquiry within its terms of reference. A comprehensive bibliography on soil science is appended to this report, for the several territories. The Central Secretariat acknowledges with appreciation the collaboration of: Professor F. Hardy, of the Imperial College of Tropical Agriculture, Trinidad, who prepared the bibliographies for individual British territories and for the independent republics, and indicated additional titles for Puerto Rico; the Department of Agriculture, Jamaica; and Dr. J.A. Bonnet and Dr. M.A. Lugo Lopez of the Agricultural Experiment Station of the University of Puerto Rico. The attention of interested specialists is invited to the bibliography included in the companion volume, Forest Research Within the Caribbean Area, published by the Caribbean Commission in 1947, and to the pertinent sections of the bibliography included in the Year Book of Caribbean Research, 1949 Supplement. Part I, Agriculture, Forestry, Fish and Wildlife, published by the Caribbean Commission in 1950.

LAWRENCE W. CRAMER  
Secretary General  
Caribbean Commission

The Anglo-American Caribbean Commission was created by the Governments of the United States and the United Kingdom on March 9, 1942, for the purpose of encouraging and strengthening social and economic cooperation between the United States of America and its possessions and bases in the area known geographically and politically as the Caribbean, and the United Kingdom and the British Colonies in the same area, and to avoid duplication of research in these fields. On December 20, 1945, the following joint communiqué was issued: "The Governments of France and of the Netherlands have accepted an invitation extended to them by the Governments of the United Kingdom and United States of America to join the Anglo-American Caribbean Commission. The name of the Commission will be changed appropriately..." The Commission is now known as the Caribbean Commission.

The Caribbean Research Council was established by the Commission in August, 1943, to survey needs, to determine what research has been done, to facilitate research on a cooperative basis, and to arrange for the prompt dissemination of the results of research, all without limitation to the field of inquiry.

In pursuance of these objectives, a number of Research Committees has been appointed for various fields of research.

The Central Secretariat of the Commission is located at Kent House, Port of Spain, Trinidad. The work of the Secretariat is divided into two main branches: administrative and research. The Research Branch, which includes a Statistical Unit, works in close cooperation with the Caribbean Research Council and its various Research Committees.

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## PART I

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### THE BACKGROUND AND ORGANISATION OF THE CONFERENCE

(1) In August, 1943, the Anglo-American Caribbean Commission, meeting in St. Thomas, placed particular emphasis on the urgency of the soils problem in the Caribbean. Its minutes read as follows :

"The most urgent need of the Caribbean region is more intensive use of the land . . . . The first step is the soil survey; this should not be over-elaborated, and should employ a uniform nomenclature agreed upon for the Caribbean. Investigations on the adaptation of new crop plants to local environments and season, rotation, tillage, manuring and crop practices generally should be guided by this soil survey."

(2) In its public report, Agriculture, Nutrition, Fisheries and Forestry, the Commission elaborated on this matter, as follows :

"The conservation and wise use of soil, water and forest resources is basic to the welfare of the Caribbean area. Poor practices in the past, however, have led to wastage and impoverishment of the soils and to depletion and reduced productivity of the forests. This degradation of the land has resulted in reduced production of cultural crops, timber, fuel, and water and in a lower standard of living of the people who are dependent upon the land for livelihood. Better treatment and use of the land so that it can produce more abundantly will lead to a better standard of living for the people.

"The problems in need of research in these fields are many and diverse. Collaboration within the area, in the planning and development of research and in the exchange and dissemination of results, offers the chief hope of achieving greatly improved soil, water and forest conservation in the shortest time.

"Inter-relationships in Conservation : Soil conservation is seldom an end in itself. It is chiefly a means to sustained or increased production of plants, whether they be cultivated crops, permanent pasture, forest or lands maintained solely for the conservation of water. Soil conservation must be developed for and in accordance with the requirements of each kind of plant or crop production. The more serious soil conservation problems in the Caribbean area are on the cultivated land, particularly on the steeper lands.

"One group of problems in water conservation involves such aspects as the retention of soil moisture for crop production, control of runoff to



prevent erosion, regulation of streamflow, and control of floods. Achievement in this group depends largely upon the development and application of cultivation and cropping practices suited to particular conditions, supplemented with engineering devices to control runoff.

"Another group of problems in water conservation is concerned with the control and beneficial use of water for domestic and industrial purposes, hydroelectric power development, and to some extent irrigation. These questions involve chiefly the control and management of the water after it reaches the streams or storage basins, but the quantity of the flow depends usually upon the measures undertaken with respect to the first group.

"Lands suited for Forest : Land unsuited to cultivation or arable crops, fodder grasses, or permanent pasture because of conditions of soil, steepness of slope or climate should, in so far as practicable, be kept in forest. This is necessary for the prevention of soil erosion, conservation of runoff, and the maximum production of forest crops, including desirable recreational use and the maintenance of a suitable environment for fresh water fish and wild life. By keeping the land more permanently in cover, forests are more suitable for those lands most vulnerable to rapid runoff and erosion. Besides adapting forest management to soil and water conservation, other problems requiring research include those dealing with more efficient production from the land and the greater home and industrial utilization of forest crops."

(3) It was upon the foregoing inter-relationship of soil, water and forest conservation that the Anglo-American Caribbean Commission based its suggested research programme. The Commission stated with respect to this programme :

"In considering it and in instituting any specific project in the future, two important factors should be borne in mind : (a) that much scientific knowledge on soil, water and forest conservation is already available and being practiced as a result of past research and experience throughout the Caribbean area. Also considerable information developed by research on the Continents is directly applicable, or can be adapted, to the solution of many problems of the area; (b) that new research should be based upon research already done within the area or applicable research elsewhere."

(4) With respect to soil science as related to agriculture, the Commission recommended the following general fields of data that should be examined from the standpoint of present status and need for further undertakings :

"Land resources, their classification and utilization including soil

classification, topography and other physical factors that are significant in the conservation and utilization of land ...

"Present utilization of land, including areas for crop production, grazing, forestry and other purposes."

(5) This meeting of the Anglo-American Caribbean Commission resulted in the establishment of the Caribbean Research Council, to ascertain what research has been done, survey needs, advise concerning desirable research projects, arrange and facilitate cooperative research, undertake special research assignments, and collect and disseminate information concerning research. One of the earliest recommendations of this Council, approved by the Commission in 1944, was that a research survey of the Caribbean area should be undertaken at an early date. The two scientists selected for the task, Dr. Carlos E. Chardón, then Director of the Institute of Tropical Agriculture, Mayaguez, Puerto Rico, and the late D.D. Paterson, Professor of Agriculture, Imperial College of Tropical Agriculture, reported in 1945. Their chief recommendation was that a conference of soil scientists in the Caribbean area should be held at an early date. "The object of this meeting," they stated, "would be to draft for the Caribbean Commission a common basis of approach and ultimate system of soil classification acceptable to all representatives attending the meeting ... It is fundamental to any early progress towards useful soil survey, and that, in turn, is admittedly the first step to sound agricultural planning."

(6) A few months later, in January, 1946, the sub-Committee on Forestry of the Committee on Agriculture, Nutrition, Fisheries and Forestry of the Caribbean Research Council met in Trinidad. The Sub-Committee, after surveying the present state of progress with respect to soil surveys in the Caribbean area, recommended (1) standardised surveys, classification and nomenclature of all soil types of the region, through the medium of a symposium of soil scientists; and (2) detailed soil surveys of forested areas with maps suitable for local needs. The Sub-Committee also recommended a number of general research projects in the field of forestry with respect to soil factors, to be executed by, or in collaboration with, soil scientists, on a regional basis.

(7) In March of the same year, the West Indian Conference (Second Session), held in St. Thomas, Virgin Islands of the United States, recommended that an informal meeting of soil scientists from the territorial and member governments of the Commission should be held in Puerto Rico at an early date. In accordance with this recommendation, a Preparatory Committee, representative of the four member governments, was appointed in 1947 to prepare an agenda for the conference. The composition of the Preparatory Committee was as follows :

## SOIL SCIENCE IN THE CARIBBEAN

- United Kingdom - Mr. H.J. Page, Chairman - Principal, Imperial College of Tropical Agriculture, Trinidad.
- Professor F. Hardy, Professor of Chemistry and Soil Science, Imperial College of Tropical Agriculture, Trinidad.
- United States - Dr. J.A. Bonnet, Head, Soils Division, Agricultural Experiment Station, University of Puerto Rico.
- France - Mr. D. Blanche, Acting Head of the Agricultural Service, Martinique.
- Netherlands - Dr. H.J. Müller, Agricultural Chemist, Department of Agricultural Economics, Surinam.

(8) This Preparatory Committee recommended the following agenda, which was approved by the Commission :

- (i) Presentation and discussion of collected data on soil forming factors of the various territories.
- (ii) Standardisation of field and laboratory methods of soil surveys.
- (iii) Discussion of different systems of soil classification and mapping.
- (iv) Formulation of a detailed regional programme of soil surveys.
- (v) Survey of problems of soil erosion, soil conservation and soil renovation in the different territories.
- (vi) Practical application of soil surveys to land utilization.

(9) Another Preparatory Committee, under the Chairmanship of Dr. Bonnet, was appointed to make all necessary arrangements for the scientific programme of the Conference. The other members of this Committee were Professor Hardy (with Mr. G. Rodrigues of the Imperial College of Tropical Agriculture as his alternate); Dr. E.M. Chenery of the Department of Agriculture, Trinidad and Tobago; Dr. Müller; and Mr. Blanche.

(10) The date originally fixed for the conference, August 1948, clashed with the British Commonwealth Soil Scientists Conference at Rothamsted. For this and other reasons, it was found impossible to convene the conference in Puerto Rico before March, 1950.

(11) The delegates, observers, visitors and Secretariat staff in attendance at the Conference were as follows :

DELEGATES

<u>Territory</u>	<u>Delegate</u>	<u>Office</u>
Barbados	Mr. J.B.D. Robinson	Agricultural Chemist, Department of Agriculture.
French Guiana	M. Paul Béna	Head, Forests and Water Conservation Service.
Guadeloupe	M. P. Moulin	Acting Conservator of Water and Forests for French West Indies.
Leeward Islands	Professor F. Hardy	Professor of Chemistry and Soil Science, Imperial College of Tropical Agriculture, Trinidad; Member of Preparatory Committee.
Jamaica	Mr. T. Owen Ellis	Senior Agricultural Chemist, Department of Agriculture.
Martinique	Dr. H. Stehlé	Director of Agricultural Research in the French West Indies and French Guiana; Member of Prepara- tory Committee.
Netherlands West Indies	Dr. J.E. Westermann	Director, Development In- formation Bureau of the Netherlands Antilles, Amsterdam.
Puerto Rico	Dr. Juan A. Bonnet	Head, Soils Division, Agricultural Experiment Station, University of Puerto Rico; Member of Preparatory Committee.
Surinam	Mr. J.M. Verhoog	Pedologist, Agricultural Experiment Station, Department of Agriculture, Surinam; Member of Preparatory Committee.

## SOIL SCIENCE IN THE CARIBBEAN

<u>Territory</u>	<u>Delegate</u>	<u>Office</u>
Trinidad and Tobago	Mr. G.C. Witt	Soil Survey Officer, Department of Agriculture.
Virgin Islands of the United States	Mr. Oscar R. Bough	Extension Agent in Charge, Agricultural Experiment Station, St. Thomas.
Windward Islands	Professor F. Hardy	Professor of Chemistry and Soil Science, Imperial College of Tropical Agriculture, Trinidad; Member of Preparatory Committee.

OBSERVERS

<u>Territory</u>	<u>Observer</u>	<u>Organisation</u>
British Commonwealth	Mr. G. Rodrigues	Lecturer, Imperial College of Tropical Agriculture, Trinidad.
	Mr. Kenneth C. Vernon	B.W.I. Soil Survey, Imperial College of Tropical Agriculture, Trinidad.
Puerto Rico	Mr. Antonio Rodríguez Colón	Appraiser, Farmers Home Administration.
	Mr. Clifford A. Kaye	Geologist, Puerto Rico Water Resources Authority.
	Mr. Rafael Perez Díaz	Division for Classification and Scientific Appraisal for Urban and Rural areas, Treasury Department.
	Mr. Fernando Abruña	Agronomist, BFI-SCS Re- search Project, Agricul- tural Experiment Station, University of Puerto Rico.
	Mr. Carlos Cernuda	Chemist, BFI-SCS Research Project, Agricultural Ex- periment Station, Univer- sity of Puerto Rico.

<u>Territory</u>	<u>Observer</u>	<u>Organisation</u>
Puerto Rico (cont'd)	Mr. Arturo Roque	Director, Agricultural Experiment Station, University of Puerto Rico.
	Dr. Bernardo G. Capó	Acting Director, Agricultural Experiment Station, University of Puerto Rico.
	Mr. Julian Roldán	Assistant Soil Chemist, Soils Division, Agricultural Experiment Station, University of Puerto Rico.
	Dr. Miguel A. Lugo	Associate Soil Scientist, Soils Division, Agricultural Experiment Station, University of Puerto Rico.
	Mr. G. Nieves Calcaño	Research Assistant in Chemistry, Soils Division, Agricultural Experiment Station, University of Puerto Rico.
	Dr. George Samuels	Associate Plant Physiologist, Plant Physiology Division, Agricultural Experiment Station, University of Puerto Rico.
	Mr. F. Aróstegui	Associate Agronomist, Agronomy Division, Agricultural Experiment Station, University of Puerto Rico.
	Mr. P. Landrau	Assistant Agronomist, Agronomy Division, Agricultural Experiment Station, University of Puerto Rico.
	Mr. F. Mendez	Associate Agronomist, Agronomy Division, Agricultural Experiment Station, University of Puerto Rico.
	Mr. W. Pennock	Associate Horticulturist, Agronomy Division, Agricultural Experiment Station, University of Puerto Rico.

<u>Territory</u>	<u>Observer</u>	<u>Organisation</u>
Puerto Rico (cont'd)	Mr. C. Rivera Lopez	Assistant Agronomist, Agronomy Division, Agricultural Experiment Station, University of Puerto Rico.
	Mr. J.P. Rodríguez	Associate Agronomist, Agronomy Division, Agricultural Experiment Station, University of Puerto Rico.
	Mr. E. Molinary Sales	Editor, Agricultural Experiment Station, University of Puerto Rico.
	Mr. P. Gonzalez Ríos	Acting Head, Genetics Division, Agricultural Experiment Station, University of Puerto Rico.
	Mr. L.B. Ortiz	Research Assistant in Agronomy, Lajas Substation, Agricultural Experiment Station, University of Puerto Rico.
	Mr. A. Riollano	Agronomist in Charge, Isabela Substation, Agricultural Experiment Station, University of Puerto Rico.
	Mr. Rafael Pietri	Assistant Professor in Agronomy, College of Agriculture and Mechanic Arts, University of Puerto Rico.
	Mr. Ruben A. Bonilla	Sugar Cane Specialist, Agricultural Extension Service, University of Puerto Rico.
	Dr. G. Serra	Head, Agricultural Economics Division, Agricultural Experiment Station, University of Puerto Rico.
	Dr. L. Alvarez	Head, Phytopathologist Division, Agricultural Experiment Station, University of Puerto Rico.

<u>Territory</u>	<u>Observer</u>	<u>Organisation</u>
Puerto Rico (Cont'd)	Mr. J. Gagtambide Arrillaga	Head, Forestry Section, Agricultural Experiment Station, University of Puerto Rico.
Food and Agriculture Organisation of the United Nations	Dr. A.B. Lewis	Land Use Officer, Land Use Branch, Agriculture Division, Food and Agriculture Organisation of the United Nations.
United States of America	Mr. R.D. Hockensmith	Chief, Soil Conservation Surveys Division, United States Department of Agriculture, Washington, D.C.
	Mr. Ray C. Roberts	Principal Soil Correlator for Western States, Division of Soil Survey, Bureau of Plant Industry, Soils and Agricultural Engineering, Berkeley, California.
	Mr. Glenn L. Fuller	Regional Soil Scientist, Southeastern Region, Soil Conservation Service, United States Department of Agriculture, Spartanburg, South Carolina.
	Dr. Roy W. Simonson	Assistant Chief, Division of Soil Survey, United States Department of Agriculture, Beltsville, Maryland.



## SOIL SCIENCE IN THE CARIBBEAN

<u>Territory</u>	<u>Observer</u>	<u>Organisation</u>
United States of America (cont'd)	Mr. U.S. Allison	Director, Soil Conservation Surveys in Puerto Rico and the Virgin Islands of the United States, Soil Conservation Service, United States Department of Agriculture, San Juan, Puerto Rico.
	Dr. Joaquin A. Marrero	Assistant Director, Soil Conservation Surveys in Puerto Rico and the Virgin Islands of the United States, Soil Conservation Service, United States Department of Agriculture, San Juan, Puerto Rico.
	Dr. Juan P. Córdova	Soil Scientist, Soil Conservation Surveys in Puerto Rico and the Virgin Islands of the United States, Soil Conservation Service, United States Department of Agriculture, San Juan, Puerto Rico.
	Mr. Juan Juárez Juarbe	Soil Scientist, Soil Conservation Surveys in Puerto Rico and the Virgin Islands of the United States, Soil Conservation Service, United States Department of Agriculture, San Juan, Puerto Rico.
	Mr. Henry B. Bosworth	Director, Tropical Region, United States Forest Service, Río Piedras, Puerto Rico.
	Dr. Frank Wadsworth	Silviculturist in Charge of Research, Tropical Forest Experiment Station, United States Forest Service, Río Piedras, Puerto Rico.

<u>Territory</u>	<u>Observer</u>	<u>Organisation</u>
United States of America (cont'd)	Mr. José Marrero	Forester, Tropical Forest Experiment Station, United States Forest Service, Río Piedras, Puerto Rico.
	Mr. William H. Gracia	District Conservationist, Caribbean Area Soil Conservation Service, Río Piedras, Puerto Rico.
	Mr. C.S. Simmons	Instituto Agropecuario Nacional, Office of Foreign Agricultural Relations, United States Department of Agriculture, Guatemala.
	Dr. R.M. Smith	In charge BPI-SCS Research Project, United States Department of Agriculture, cooperating with Agricultural Experiment Station, University of Puerto Rico.
	Mr. D.K. Fuhrman	Agricultural Engineer, BPI-SCS Research, United States Forest Research Station, Río Piedras, Puerto Rico.

VISITORS

<u>Territory</u>	<u>Visitor</u>	<u>Organisation</u>
Colombia	Dr. José M. Molina	Head, Soil Survey Department.
	Dr. Jose V. Lafaurie Acosta	Sección de Suelos, Instituto Geográfico, Bogota.
Dominican Republic	Mr. W.J. Luke, Jr.	Central Romana Corporation, La Romana.

## SOIL SCIENCE IN THE CARIBBEAN

<u>Territory</u>	<u>Visitor</u>	<u>Organisation</u>
Dominican Republic (cont'd)	Mr. Miguel A. Cesteros	Agronomist, Ministry for Conservation of Soils, Department of Agriculture, Forestry and Land Settlement, Ciudad Benemerita, P.T., San Cristobal.
Haiti	Mr. Edmond Polynice	Department of Agriculture, Port-au-Prince.
Jamaica	Mr. H.C. Thompson	Colonial Sugar Company, Monymusk.
Puerto Rico	Dr. Ismael Velez	Professor of Botany, Polytechnic Institute, San Germán.
United States of America	Dr. C.D. Jeffries	Professor of Soils, Pennsylvania State College, Pa.
	Dr. H.A. Meyerhoff	Administrative Secretary, American Association for the Advancement of Science, Northampton, Massachusetts.
Venezuela	Mr. L.M. de Eleizalde	Jefe, División de Suelos, Instituto Nacional de Agricultura, Maracay.

CENTRAL SECRETARIAT, CARIBBEAN COMMISSION

Dr. Eric Williams	Deputy Chairman, Caribbean Research Council
Mr. C.K. Robinson	Executive Secretary (Agricultural Economics)
Mr. C.P. Erskine-Lindop	Administrative Assistant.

(12) Others present who participated in the work of the Conference were :

Mr. W.W. Pate, Assistant in Research, Soils Divisions, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture.

Dr. C. Gaztambide Arrillaga, Agricultural Extension Service, Puerto Rico.

Mr. T.M. Bushnell, Soil Survey, Purdue University, Agricultural Experiment Station, Indiana.

Mr. Roberto Huyke, Agricultural Extension Service, Puerto Rico.

Mr. C.G. Moscoso, Genetics Division, Agricultural Experiment Station, University of Puerto Rico.

Mrs. Maria del C.C. Fernandez, Physiology Division, Agricultural Experiment Station, University of Puerto Rico.

Madame Madeleine Stehlé, Guadeloupe.

Mr. M.A. Hein, Agronomist, Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, United States Department of Agriculture, Beltsville, Maryland.

Mr. E. Boneta-García, Research Assistant Plant Breeder, Agricultural Experiment Station, University of Puerto Rico.

Mr. J. Martínez-Mateo, Assistant Chemist, Agricultural Experiment Station, University of Puerto Rico.

Mr. E. Hernández, Assistant, Plant Physiology, Agricultural Experiment Station, University of Puerto Rico.

Mr. M.A. Tió, Assistant, Plant Physiology, Agricultural Experiment Station, University of Puerto Rico.

Mr. J.S. Simmons, Assistant Agronomist in charge of Plant Propagation and Distribution, Agricultural Experiment Station, University of Puerto Rico.

Mr. R. Grant, Research Assistant and Agronomist in charge of Station Farm, Agricultural Experiment Station, University of Puerto Rico.

Dr. R.J. Muckenhirn, Assistant Director, Experiment Station, College of Agriculture, University of Wisconsin.

Mr. J.A. Silva, Jefe, Sección de Fertilidad, División de Suelos, Instituto Nacional de Agricultura, Maracay.

Mr. L.J. Medina, Jefe, Sección de Estudios, División de Suelos, Instituto Nacional de Agricultura, Maracay.

## SOIL SCIENCE IN THE CARIBBEAN

(13) The Conference was opened by Dr. Jaime Benitez, Chancellor of the University of Puerto Rico. Opening addresses were also made by Dr. Eric Williams, Deputy Chairman, Caribbean Research Council, and Dr. Bernardo G. Capó, Acting Director, Agricultural Experiment Station, University of Puerto Rico.

(14) The Conference elected Dr. Juan A. Bonnet chairman, and appointed three committees, as follows :

COMMITTEE I - SOIL SURVEYS

Dr. Roy W. Simonson, Chairman	- United States of America
Professor F. Hardy, Rapporteur	- Imperial College of Tropical Agriculture, Trinidad
Mr. G.C. Witt	- Trinidad
Mr. Ray C. Roberts	- United States of America
Mr. Juan P. Córdova	- United States of America
Dr. José M. Molina	- Colombia
Mr. L.J. Medina	- Venezuela
Dr. J.A. Bonnet	- Puerto Rico
Dr. C.D. Jeffries	- United States of America
Mr. T.M. Bushnell	- United States of America
Mr. J.M. Verhoog	- Surinam
Dr. Henri Stehlé	- Martinique
Mr. C.S. Simmons	- United States of America (Guatemala)
Mr. G. Rodrigues	- Trinidad
Mr. Kenneth C. Vernon	- Trinidad
Mr. F.C. Darcel	- Trinidad
Dr. G. Samuels	- Puerto Rico
Mr. W.W. Pate	- United States of America
Dr. M.A. Lugo	- Puerto Rico
Mr. R. Pietri	- Puerto Rico
Dr. R.M. Smith	- Puerto Rico
Mr. L.M. de Eleizalde	- Venezuela

COMMITTEE II - SOIL CONSERVATION

Mr. U.S. Allison, Chairman	- United States of America
Mr. J.B.D. Robinson, Rapporteur	- Barbados
Mr. T.O. Ellis	- Jamaica
Mr. Miguel A. Cestero	- Dominican Republic
Dr. J.H. Westermann	- Netherlands West Indies
Dr. Joaquin A. Marrero	- United States of America
Dr. C. Gaztambide-Arrillaga	- Puerto Rico
Mr. Oscar R. Bough	- Virgin Islands of the United States
Mr. W.J. Luke (Jr.)	- Dominican Republic

COMMITTEE III - LAND CLASSIFICATION

Mr. R.D. Hockensmith, Chairman	- United States of America
Dr. A.B. Lewis, Rapporteur	- Food and Agriculture Organization of the United Nations
Mr. P. Béna	- French Guiana
Dr. R.J. Muckenhirn	- United States of America
Mr. G.L. Fuller	- United States of America
Dr. G. Serra	- Puerto Rico
Mr. J. Marrero	- Puerto Rico
Mr. R.A. Bonilla	- Puerto Rico
Mr. M.A. Hein	- United States of America
Mr. R.B. Batchelder	- United States of America
Dr. John Lounsbury	- United States of America
Mr. H.C. Thompson	- Jamaica
Mr. Edmond Polynice	- Haiti

(15) The Conference also appointed a Drafting Steering Committee, comprising the Preparatory Committee and the chairman of the three conference committees. The composition of the Drafting-Steering Committee was, therefore, as follows :-

Dr. Juan A. Bónnet, Chairman  
 Professor F. Hardy  
 Dr. H. Stehlé  
 Mr. J.M. Verhoog  
 Dr. Roy W. Simonson  
 Mr. U.S. Allison  
 Mr. R.D. Hockensmith  
 Dr. Eric Williams )  
 Mr. C.K. Robinson ) Central Secretariat

The Drafting-Steering Committee agreed to coopt Dr. Westermann of the Netherlands West Indies and Dr. Lewis of the Food and Agriculture Organization in order that their specialized knowledge might be at its disposal for the consideration and co-ordination of the Committee reports.

(16) The Conference also had, for its consideration, detailed statements surveying existing conditions, emphasising special problems, and making recommendations, for the following territories : Barbados, British Guiana, British Honduras, French Guiana, Guadeloupe, Leeward Islands, Jamaica, Martinique, Netherlands West Indies, Puerto Rico, Surinam, Trinidad and Tobago, Virgin Islands of the United States, Windward Islands. A similar statement for Haiti was submitted to the Secretariat during the Conference. Information was also submitted in respect of certain territories regarding personnel and funds available for research in the field of soil science. These statements had been requested by the Central Secretariat in accordance with the following

recommendations of the Caribbean Research Council at its Second Meeting, held in Trinidad in May, 1949, and approved by the Caribbean Commission at its Ninth Meeting, held in St. Thomas in December, 1949 :

- "12. That the Yearbook (of Caribbean Research) should be supplemented by separate booklets surveying over a period of time the work done in each field, as, for example, the booklet on Forest Research in the Caribbean Area.
- "13. That these separate booklets should contain bibliographies of the work done in each field, similar to the bibliography included in Forest Research in the Caribbean Area, while each edition of the Yearbook should include a bibliography of periodical literature and books published during the intervening period."

## PART II

### SEMINARS

(17) The Conference had before it, for its consideration as a guide to its deliberations, the following papers, which were duplicated and distributed by the Secretariat :

1. The Soils of Antigua, by F. Hardy.
2. The Soils of Barbados, by F. Hardy.
3. The Soils of British Guiana, by F. Hardy.
4. The Soils of British Honduras, by F. Hardy.
5. Soil Formation in the British Caribbean Volcanic Islands, by F. Hardy and J.S. Beard.
6. Brief Note on the Soils of Jamaica, by F. Hardy.
7. The Soils of Trinidad, by F. Hardy.
8. The Soils of Tobago, by F. Hardy.
9. Brief Description of Geology, Climate, Physiography and Soils of Puerto Rico, by J.A. Bonnet.
10. A Preliminary Note on Soil-Forming Factors and Soil Formation in Surinam, by J.M. Verhoog.
11. Soil-Forming Factors in the Netherlands West Indies, by H.J. Müller.
12. Lessons from the First Half Century of Soil Survey, by Roy W. Simonson.
13. La Colonisation Végétale Primaire sur les Depots Recents de Nuages Denses de la Montagne Pelée (Primary Plant Colonisation on the Recent Ash and Dust Deposits of Mount Pelée), by H. and M. Stehlé.
14. Métodos de Levantamiento y de Analisis de Laboratorio de la División de Suelos del M.A.C. (Methods of Sampling and Laboratory Analysis of the Soils Division of the M.A.C.), by Arnauld Haspil.
15. Les Sources de l'Humus et de la Matière Organique aux Antilles Françaises (Sources of Humus and Organic Matter in the French West Indies), by H. Stehlé.
16. L'Evolution de la Connaissance Pédologique des Précolombiens Insulaires à nos jours aux Antilles Françaises (The Evolution of Pedological Knowledge from the time of the Insular Pre-Columbian Inhabitants to the present time in the French West Indies), by H. & M. Stehlé.
17. Les Pionniers de la Colonisation Végétale sur les Cuirasses Latéritiques en Guadeloupe (The Pioneers of Plant Colonisation on Lat-eritic Carapaces in Guadeloupe), by H. Stehlé.
18. Breves Consideraciones Sobre los Métodos Utilizados para la Classificación y Mapeado de Suelos (Brief Discussions of the Methods used in the Classification and Plotting of Soils), by Luis J. Medina.
19. Les Principes des Travaux Cartographiques des Sols Dans les Pays à Agriculture Intensive et Mercelée (The Principles of Cartographic work in connection with Soils in countries with Intensive Agriculture and Land Settlement), by J. Baeyens.
20. Méthodes Employées en Haiti dans l'Etude des Sols (Methods employed in Haiti in the study of Soils).



21. La Signification des Normes Chimiques du Besoin en Engrais des Sols Agricoles (The Significance of Chemical Norms in the need for Fertilizers for Agricultural Soils), by J. Baeyens.
22. On the Occurrence of "Katteklei" (Cat-Clay) in Surinam, by H.J. Müller.
23. Soil Conservation, A World Opportunity, by H.H. Bennett.
24. Notes on Tropical Climatology, by C.W. Thornthwaite.
25. Some Paleosols of Puerto Rico, by Clifford A. Kaye.
26. Characteristic Clay Minerals of Some Soil Types of the Lesser Antilles, by G. Rodrigues.
27. Laboratory Methods for Soil Analysis in use at Agricultural Experiment Station, Paramaribo, Surinam, by H.J. Müller.
28. Soil Survey in the Union of South Africa, by C.R. van der Merwe.
29. Soil Classification for Irrigation Purposes in Puerto Rico, by J.A. Bonnet.
30. British Caribbean Soil Survey, Imperial College of Tropical Agriculture - St. Vincent, Soil Survey Report, by K.C. Vernon.
31. The Chemical and Physical Properties of the Zonal Soils of the Hawaiian Islands, by G. Donald Sherman.
32. Remarks about Soil Classification in the Caribbean Area with special reference to Jamaica Soils, by R.F. Innes.
33. Assessment system in Puerto Rico with special reference to Rural Areas, by David A. Rodrigues.
34. Reconnaissance Soil Classification in Extensive Areas of Level Land in the Coastal Plain of the Dominican Republic, by J.A. Bonnet.
35. The Constituent Minerals of Soils as related to Soil Problems, by C.D. Jeffries.
36. Naming and Describing the Colours of Soils, by Robert L. Pendleton.
37. Use of Soil Inventory Forms, by R. Earl Storie.
38. A Land Capability Inventory Basic to Soil Conservation, by R.D. Hockensmith.
39. A System of Soil Profile Characterization, by R.M. Smith and George Samuels.
40. The Soils of Guatemala, by Lawrence C. Wheeting.
41. Soil Survey in Surinam, by J.M. Verhoog.
42. Some Notes on Standardization of Methods of making Soil Surveys, by C.S. Simmons.
- 43\* Rapport sommaire sur les sols de la Guyane (A Brief Survey of the Soils of French Guiana), by Paul Béna.
44. Soil as a Factor in the Occurrence of Two Types of Montane Forest in Puerto Rico, by Frank H. Wadsworth and J.A. Bonnet.
45. The Genesis and Morphology of Hawaiian Ferruginous Laterite Crusts, by G. Donald Sherman.
46. Land Classification Programme in Puerto Rico, by Donald D. Dyer and C.F. Jones.
47. Land Classification Scheme in Colombia, by J.V. Lafaurie Acosta.
48. Soil Development in Puerto Rico and Surinam, by Ray C. Roberts.
49. Geologic Backgrounds in Caribbean Lands, by Howard A. Meyerhoff.

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\* Not distributed.

50. Some Observations on Soil Conservation Practices in Two Islands of the Caribbean Archipelago, St. Thomas and St. Vincent, by Ismael Velez.
51. Soil Maps as an aid in Classifying Rural Land for Recommended Use, by A.B. Lewis.
52. Classification and Mapping of Soils, Classification of Land for Recommended Use, Soil and Water Conservation, and Land Utilization as Integral Parts of a Land Improvement Programme, by A.B. Lewis.
- 52\*. Notes sur les Moyens d'Action du Service Forestier pour la Conservation et l'Amélioration des Sols dans le Département de la Guadeloupe (Notes on the Measures taken by the Forest Service for Soil Conservation and Improvement in Guadeloupe), by P. Moulin.

(18) The organisation of the Conference did not permit the reading or discussion of those papers. In order to obviate the disadvantages arising from a mere distribution of papers, and to facilitate that exchange of views which is a fundamental aspect of technical conferences of this nature, the Preparatory Committee endorsed a Secretariat proposal for the organisation of a number of evening seminars on "The Soil Problems of the Caribbean and the Adjacent Countries", as follows :

<u>Date</u>	<u>Chairman</u>	<u>Speakers</u>	<u>Subject</u>
Sunday, April 2	Dr. J.A. Bonnet	Mr. R.D. Hockensmith Dr. A.B. Lewis	Land Classification in a Caribbean Land Improvement Programme
Monday, April 3	Prof. F. Hardy	Dr. Roy W. Simonson  Dr. Ismael Velez	Soil Research and Classification in a Caribbean Land Im- provement Programme  Soil Conservation in the Caribbean
Tuesday, April 4	Mr. J.M. Verhoog	Prof. F. Hardy Mr. G. Rodrigues	Present State of Soil Knowledge in the British Caribbean
Wednesday,** April 5	Mr. G. Rodrigues	Mr. J.M. Molina  Mr. C.S. Simmons  Mr. M.A. Cesteros Mr. W.J. Luke, Jr.	Soils of Venezuela  Soils of Guatemala  Soils of the Dominican Republic

\* Not distributed.

\*\* Afternoon session.

## SOIL SCIENCE IN THE CARIBBEAN

<u>Date</u>	<u>Chairman</u>	<u>Speakers</u>	<u>Subject</u>
Wednesday, April 5	Dr. H. Stehlé	Mr. Ray C. Roberts	Soils of Puerto Rico
		Dr. J.A. Bonnet	
		Dr. C.D. Jeffries	
		Dr. H.A. Meyerhoff	
		Dr. J.V. Lafaurie Acosta	Soils of Colombia
Thursday, April 6	Dr. J.A. Bonnet	Mr. J.M. Verhoog	Soil problems of Surinam
		Dr. H. Stehlé	Soils of French Antilles
		Mr. Paul Béna	Soils of French Guiana
		Mr. P. Moulin	Conservation and Improvement of Soils of Guadeloupe
Friday, April 7	Prof. F. Hardy	Mr. U.S. Allison	Soil Conservation in Puerto Rico and the Virgin Islands of the United States
		Dr. Joaquin A. Marrero	
		Mr. Juan P. Córdova	
		Dr. R.M. Smith	

### PART III

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#### SURVEY OF EXISTING CONDITIONS, PROBLEMS AND RECOMMENDATIONS FOR THE CARIBBEAN AREA

(20) As stated above, the Conference organized three committees for the consideration of the agenda on a regional basis, in the light of the detailed tabulated statements presented for the individual territories. The Conference's report is as follows :

Survey of Existing Conditions

Problems

Recommendations

I. SOIL FORMING FACTORS

(1) Geology

(a) Amount of information variable; some territories have considerable information, others very little.

More information needed to fill in the gaps.

Various geological institutes should be approached by the Caribbean Commission for practical aid; i.e., for extension of geological surveys (British Colonial Office, U.S. Geological Survey, Surinam Bureau of Geology, French Scientific Research, Departments of Geology, Netherlands Universities).

(b) A complete bibliography was published in 1938 (L.M.R. Rutten, Bibliography of the Geology of the West Indies, Utrecht).

An up-to-date list of works in geology for the Caribbean Region is needed.

Territories should be requested by the Commission to bring the 1938 bibliography up-to-date and to keep it posted.

(2) Topography

(a) Kinds and degree of accuracy of topographic maps variable.

Need for standardisation of maps and for maps of different scales.

Caribbean Commission should request the territorial Governments to expedite the completion of surveys in their territories.

(b) Few territories have aerial surveys completed.

Great need for completion of aerial surveys for all territories.

Best scales of maps to be produced and used should be determined. A scale of 1:20,000 is satisfactory for aerial photo negatives. Enlargements to the required scale should be made from these negatives.

(c) Few have topographic maps based on aerial surveys available.

Need for topographic maps based on aerial surveys.

Survey of Existing Conditions

Problems

Recommendations

(3) Climate

- |  |   |  |
|--|---|--|
| (a) Variable rainfall data available, particularly for cultivated areas. | Need for more rainfall stations especially in lesser developed areas. | Seek aid from meteorological authorities, local meteorological and agricultural departments for purpose of multiplying stations and installing additional instruments.   |
| (b) Only sparse data for intensity of rainfall available.                | Need for more recording rain gauges.                                  |  |
| (c) Only sparse data for variations of temperature and wind available.   | Need for more temperature stations.                                   | The Caribbean Commission should draw to the attention of the proposed Meteorological Conference in June, 1950, the need for increasing the number of stations and installing additional equipment, particularly recording instruments. |

Additional :

- (i) Need for evaporation (evapotranspirometric) data.

- (ii) Need for dew measurements.

Recommendation to Meteorological Conference as above.

(4) Vegetation

- |   |  |  |
|---|--|--|
| Fair amount of information available for most territories. Floras and herbaria for a few territories are available. | Need for filling in the gaps and for more detail concerning undergrowths, second-growth successions and weeds as "soil markers". | Seek further aid from Forest and Agricultural Departments and local and metropolitan botanists and institutions. |
|---|--|--|

Survey of Existing Conditions

Problems

Recommendations

II. STANDARDISATION OF SOIL SURVEY METHODS

(1) Field Methods

(a) Little experience outside of Puerto Rico, Trinidad-Tobago, British Honduras, Antigua and Surinam, where detailed soil surveys have already been made.

A need for development of methods by further experience.

The individual organisations should seek the cooperation of soil-survey organisations which possess the necessary information, experience and knowledge.

(b) Mostly profile-pit and auger methods have been used.

Exchange of information and experience required concerning both methods and equipment (e.g., kinds of augers and boring implements).

Soil surveyors in the different territories might prepare a list and description of the methods and equipment in use for circulation among all territories.

(2) Laboratory Methods

(a) There is considerable variation in the methods used in the laboratories of the different territories, partly because the present needs are variable.

The need for special equipment (e.g., the flame photometer) was expressed, and also detailed instructions as to how to use and maintain such apparatus under tropical conditions.

Soil chemists in the different territories might prepare a list and description of the methods in use in their laboratories for general circulation by the Commission's Secretariat.

(b) The following routine determinations are made in most laboratories :-  
mechanical analysis,  
pH, calcium carbonate,  
organic matter, total  
nitrogen, available phosphate and potash.

The need of additional junior trained staff was expressed for Trinidad, Tobago, and Surinam.

The need of a soils laboratory for French Guiana was indicated by the French dele-

Grants be sought by the Commission to help to establish soils laboratories where none exist, to enlarge the staffs of laboratories at present inadequately staffed, and for the purchase of special equipment, where required.

Survey of Existing Conditions

Problems

Recommendations

(2) Laboratory Methods

(b) (Contd.)

Many determine exchange capacity and exchangeable bases as routine work, and some measure chloride and sulphate. A few determine lime-requirement as routine.

gates.

The need was expressed of mineral analyses by special methods (e.g., X-ray, differential thermal analysis and X-ray spectroscopic methods), possibly to be undertaken at a Central Laboratory. It was indicated, however, that if such a laboratory were contemplated, the equipment might rapidly deteriorate because of high humidity; hence, samples may have to be sent abroad for examination.

Instrument makers be invited by the Commission to consider the design and manufacture of damp-proof apparatus of the kinds referred to in the second column as well as other electrical equipment.

Lists of equipment makers should be furnished the Commission by the Soils Laboratories in the area.

(c) Routine physical determinations (e.g., of structure and pore-space) are not generally undertaken.

The study of physical methods should be extended, and consideration given to their application as routine determinations.

Enquiries be made by the Commission into the possibility of modifying existing quarantine and customs regulations to expedite the exchange of soil samples and the delivery of samples to any Central Laboratories that might be established in the Caribbean region.

Information should be sought by individual scientists from investigators having experience of physical methods of soil analysis and their application to routine work for dissemination in the



Survey of Existing Conditions

Problems

Recommendations

26

(2) Laboratory Methods

(c) (Contd.)

Caribbean region.

III. SYSTEMS OF SOIL CLASSIFICATION

Systems so far used have been mostly petrological, except Puerto Rico, St. Croix, Antigua and Surinam, where pedological system was used. Drainage has been used in classifying the soils of Trinidad-Tobago and British Honduras.

Need for standardisation and comparison with Puerto Rico system.

Individual organisations should seek aid from USDA authorities, particularly from those who have had experience with soils in Puerto Rico.

IV. DETAILED REGIONAL PROGRAMMES OF SOIL SURVEY

The extent of surveyed areas and the intensity of the survey vary greatly, from nil in some areas to complete detailed surveys in parts of Surinam, Trinidad, Antigua, and Puerto Rico.

Soil surveys are needed in different degrees of intensity for most territories; for example, land settlement in Surinam, arable land in the Netherlands West Indies, most of the lands of Jamaica, unsurveyed parts of Trinidad and Tobago, parts of British Guiana and British Honduras, the whole of the British Leeward and Windward Islands, the French territories, and the Virgin Islands, both

Individual territories should establish survey organisations or extend activities of existing survey organisations, as appropriate.

Survey of Existing Conditions

Problems

Recommendations

IV. DETAILED REGIONAL PROGRAMMES OF SOIL SURVEY (Contd.)

United States and British,

V. SOIL EROSION, CONSERVATION AND RENOVATION

In view of improper land use as a result of certain social and economic conditions in the Caribbean area, and with special reference to topography, climate and soil types, soil erosion has become a very serious problem.

(a) No systematic survey of soil erosion has been carried out in most of the territories.

Inability on the part of territories to provide sufficient technical personnel and laboratory facilities required for the procurement of necessary information.

Individual Governments should be urged to establish erosion surveys.

The methods in use in Puerto Rico, or modifications to suit local conditions, should be considered by other territories.

Reconnaissance data on erosion and other factors of importance to soil conservation should be mapped at the time of the basic soil survey, as aids in determining a need for a soil and water conservation programme.

Survey of Existing Conditions

Problems

Recommendations

V. (a) (Contd.)

(b) A definite need is apparent in most territories for a programme of soil and water conservation.

There is a general lack, over much of the area, of the necessary territorial organisation.

Lack of enabling legislation in most territories, which is essential for the initiation and implementation of adequate conservation programmes, is a limiting factor.

(c) Lack of technical data on factors affecting erodibility of soils.

Information is required on precipitation, evaporation, run-off, percolation and other factors.

Solicit technical and financial assistance under the Expanded Technical Assistance Programme of the United Nations and individual governments, the Economic Cooperation Administration, the Food and Agriculture Organisation of the United Nations, the Conservation Foundation (New York), and other sources.

The necessary organisation should be provided in these territories.

The territories should enact appropriate legislation, such as the Soil Conservation Districts Act in force in Puerto Rico and the Virgin Islands of the United States, which will provide for the proper execution of suitable conservation programmes.

Such legislation should provide for the appropriation and use of funds, control of forest reserves and watershed areas, and the control of water and soil whenever these affect the public welfare.

Research on these lines should be instituted by individual territories.

Survey of Existing Conditions

Problems

Recommendations

- |   |  |   |
|---|--|---|
| (d) Lack of land capability maps in many territories.   | Absence of necessary data on which to base land capability surveys.  | As soon as the necessary basic data become available, land capability maps should be prepared in the territories.   |
| (e) There is lack of popular understanding of basic principles of soil erosion and soil conservation in their broadest aspects. | In view of the fact that the application of soil conservation methods depends greatly on the attitude of the population, it is felt to be of great importance that the people be made conservation minded. | The territories are requested to consider the various ways and means of disseminating conservation information amongst the population. This could be achieved primarily by education, including lectures, moving pictures, and by the distribution of appropriate educational material. |
| (f) In most of the territories, conservation farm planning is not undertaken.   | Deficiency of technical knowledge in soil conservation.<br><br>Inadequate services for the dissemination and interpretation of scientific information.   | Governments should be urged to establish the necessary organisations to extend technical knowledge and assistance to the agricultural population, where such organisations are not already established.   |
| (g) There are large areas of land which have become unsuited to cultivation through soil erosion in this area.                  | Difficulty of conversion to more desirable land use, owing to population pressure and other social and economic factors, in many cases.  | If and where possible, these lands should be converted from cultivated crops to pasture, forage and forest cover crops in these areas.  |
| (h) There is no unified soil conservation programme throughout the Caribbean area.  | Lack of coordination among the territories and the agencies participating in soil conservation in the Caribbean area.  | A Co-ordinating Soil Conservation Committee should be appointed by the Commission to act as an overall committee to guide soil conservation work in the Caribbean area.   |

This committee should be composed of specialists in the field of

Survey of Existing Conditions

Problems

Recommendations

V. (h) (Contd.)

Many territories or parts of territories have similar soils, topography, and crop conditions, but there is inadequate information concerning their distribution and extent. This information is needed to reduce the expenses of research resulting from duplication of effort.

The definition of these areas will depend on the completion of soil and land surveys.

conservation and related subjects.

This Committee should collect and disseminate all available and future information and publications on soil erosion, conservation, renovation, legislation and related subjects, through the facilities of the Caribbean Commission.

The Co-ordinating Soil Conservation Committee should expedite the completion of the necessary surveys and the designation of similar land areas.

VI. LAND CLASSIFICATION

(1) Base Maps

Adequate base maps are essential in collecting and interpreting the data needed in making both land capability classification and economic land use classification.

The principal problem involved in acquiring more and better base maps is that of finance. In some cases, there are problems of procedure involved in arranging for maps and photographs in the possession of one Govern-

The necessary steps should be taken by governments to provide aerial photographs for their territories for use in land classification. Such photographs should be to a scale at least 1:20,000, and, preferably, 1:10,000.

Survey of Existing Conditions

Problems

Recommendations

(1) Base Maps (Contd.)

Adequate base maps and aerial photographs are available only for a portion of the Caribbean area.

ment to be used by another Government.

The United States Section of the Caribbean Commission should be requested to arrange to make available to the territories of other Sections of the Commission either the negatives of aerial photographs made by the United States Army in various Caribbean territories or enlargements based upon such negatives.

The United States Section of the Commission should be requested to explore the possibilities of the United States Armed Forces extending their coverage of aerial photographs over other territories of the Caribbean, not yet photographed.

The United States Section of the Caribbean Commission should be requested to determine the extent to which the United States Coast and Geodetic Survey has made topographic maps of Caribbean areas; to make such maps available to the other Sections of the Commission for use in land classification; and to explore the possibility of the work of the United States Coast and Geodetic Survey being extended into other Caribbean territories not yet covered.

Survey of Existing Conditions

Problems

Recommendations

(1) Base Maps (Contd.)

Cadastral maps of Caribbean territories, made through the use of aerial photographs and other means, should be completed as soon as possible in view of their value in land classification and for other purposes.

(2) Land Capability Classification

Land capability and similar maps have been made for only a small part of the area.

Shortage of funds and, particularly, of trained personnel for extending land capability classification.

Because of the shortage of trained personnel, there is a possibility that work in the various parts of the several Caribbean territories will be done from different points of view and based on different principles.

Land capability classification should be initiated in all Caribbean territories or completed in territories where it has already been begun, as a guide for public policies and private practices in land utilisation.

In the process of making land capability maps, maps of existing land use on farms would be prepared as an incidental part of the land capability classification.

It is highly desirable that land capability classification should proceed on a basis of uniform principles, so that the results may be comparable and interchange of information facilitated.

The Caribbean Commission should explore the possibilities of obtaining technical assistance

Survey of Existing Conditions

Problems

Recommendations

(2) Land Capability Classification (Contd.)

through the United Nations Expanded Technical Assistance Programme and other sources in the training of personnel for, and in the planning and initiation of, programmes of land capability classification as part of a Caribbean Land Improvement Programme.

(3) Farm Management Research

Farm management studies are necessary as a basis for economic land classification, as well as for other research on the factors influencing the success of individual farmers.

Lack of funds, and, principally, shortage of personnel trained in the principles and methods of farm management analysis.

Farm management studies should be initiated in all territories of the Caribbean where they have not already been begun, and should be expanded in most of the territories where work has already been started.

For most of the Caribbean territories, with the exception of Puerto Rico, little farm management research has been done.

The Caribbean Commission should explore the possibility of obtaining technical assistance through the United Nations Expanded Technical Assistance Programme and from other sources, in the training of agricultural personnel in the principles and methods of farm management analysis.

(4) Economic Land Classification

No work has been done, ex-

Shortage of personnel ade-

Economic land classification maps



Survey of Existing Conditions

Problems

Recommendations

(4) Economic Land Classification  
(Contd.)

cept in Puerto Rico.

quately trained in the principles of farm management and economic land classification to undertake and supervise the work. A secondary problem is that of obtaining funds for such classification.

should be prepared as rapidly as it is possible to obtain or train the necessary personnel in all Caribbean territories where they have not yet been completed. Detailed maps of the present use of the land would be made as an integral part of the process of classifying the land into economic land use classes. These land use maps would be more detailed and more specific than those required for the land capability classification described previously.

The Caribbean Commission should explore the possibility of obtaining technical assistance through the United Nations Expanded Technical Assistance Programme and from other sources, in obtaining and training personnel for economic land use classification in the Caribbean.

## PART IV

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### RECOMMENDED LAND IMPROVEMENT PROGRAMME FOR THE CARIBBEAN AREA

#### Preamble

(21) The Conference has given the most careful consideration to the interest taken by the Caribbean Commission in the Soil and Land problem of the area, to the hope that it has generally expressed for practical and practicable recommendations, and to the acuteness of the agricultural problems of the area which are to be the theme of the West Indian Conference (Fourth Session), to be held in Curacao in November, 1950.

(22) No resource is of such importance in the support of mankind as the land, including its water supply, on which crops, farm animals, and forests are produced. At the same time, however, the misuse and under-development of this resource are widespread, giving rise to hardships and losses, and limiting the living levels of entire populations, especially those who obtain their living directly from the land. These conditions are seen in many parts of the Caribbean area.

(23) Fortunately, ways and means have been devised and used in various countries in preventing the misuse of land resources, developing the potentialities of various kinds of land, and thus safeguarding and improving the livelihood of the people. For the successful planning and conduct of such land utilisation programmes, however, basic information of a scientific nature must be obtained, and organizations and activities must be established and initiated for this purpose. These activities are designed, essentially, to determine and show the varying characteristics of land that should govern decisions by the public and by private persons as to how the land is to be used to the best advantage. These essential activities may be briefly described as follows :

(24) (a) The soil survey, with accompanying soil classification and research, determines and shows the characteristics of the many types of soil, their origin and how they have been formed, and their geographic relation to each other. Soil research determines response of the soil to fertilizers, cultivation, and other management factors. Soil maps can be made only by soil scientists trained in the subject. As base maps for soil surveys, aerial photographs and topographic maps are required.

(25) (b) The land capability map classifies the land within farms and within fields according to the use and treatment to which the land is adapted from the physical and agronomic point of view, as distinct from the general economic characteristics of large areas. It is a detailed classification, such as is useful to an individual farmer in planning the

use and treatment of each separate portion of his farm.

(26) In the land capability classification many land characteristics are considered. These include the soil and such factors as slope, stoniness, rock outcrop, climate, drainage, and past soil losses by erosion. On all these bases the land is first classified as to whether or not it is useful for cultivation. Land suited to cultivation is subclassified according to the number and force of limitations it possesses as to its use and treatment. The land not suited to cultivation is similarly subclassified as to limitations of use and treatment under uses not requiring cultivation, such as, for example, forest or grazing.

(27) Determination of land capability classes is not merely a matter of field mapping, but is based on scientific investigations made by specialists in various sciences. It is an art based on science, and can be accomplished only by adequately trained personnel. For land capability surveying and mapping, aerial photographs and cadastral survey maps are needed as base maps. Soil information and relationships obtained in the soil survey and soil research are utilized in classifying land from the land capability viewpoint.

(28) (c) Farm management surveys and research are conducted in order to determine and show the importance of various factors, including the character of the land, in influencing farming returns and the improvement and development of farms. Information so obtained is indispensable in guiding the reorganisation of farms based on land capability maps, in establishing standards for economic land classification, described below, and for many other purposes.

(29) (d) Economic land use classification is a generalised classification of larger areas, within which farms are situated, from the viewpoint of the degree of intensity of use to which the land is adapted. The economic land classification serves as a guide for public programmes intended to improve land utilisation and to develop land resources as well as for private decisions of a fundamental nature involving land use. Among these programmes is that of soil and water conservation, for which the land capability maps (described above) are necessary in dealing with problems on a farm-by-farm basis or on groups of farms whose conservation problems are related. Other public land improvement programmes for which the economic land classification serves as a basis and guide include new agricultural settlements, reforestation, rural electrification, extension or improvement of irrigation and drainage, improvement of rural roads, planning of rural school systems, and guiding the formation of policy and the conduct of programmes in the fields of land taxation, rural credit, rural fire insurance, agricultural extension or advisory work amongst farmers, and others. Such maps also serve as an indispensable framework for agricultural economic research, especially farm management and land economic research.

(30) Economic land use classification maps are made by specialists with training in the principles of farm management and land economics and with the necessary field experience. The base maps required are topographic maps and aerial photographs. In the classification, soil survey maps or land capability maps, or both, are used, while economic data including detailed data on existing land use are also considered.

(31) The foregoing activities establish a reliable basis for a land improvement programme in any area where they are carried out. In view of past experience, it is certain that programmes intended to regulate, improve, or develop the use of land resources can be safely planned and conducted only on such a basis.

(32) It is recognized, however, that countries or territories carrying out such activities only do so through the use of considerable funds and trained personnel, and that programmes must be adapted to the resources of governments as well as the needs of their territories.

It is desirable, for example, to have a complete land capability map of an area available before making an economic land use classification map of that area, but it is possible and sometimes necessary to make an economic land class map before a complete land capability map can be made. In that case, the economic land classification is based on whatever physical, soil and other land data are available, together with data on land use and other economic factors. Similarly, it is best to have at least a soil association map of the territory to be classified and detailed soil surveys of sample areas before a land capability classification or economic land use classification is initiated; but the urgent need of land capability maps and economic land use maps may require that classification of both kinds be begun before the basic soil studies have been completed to this extent.

#### Recommendations

(33) The Conference, therefore, recommends :-

1. That each Caribbean territory that has not already done so initiate within its boundaries a comprehensive Land Improvement Programme; and that a high degree of coordination of effort be maintained as between the various territories in the planning and carrying out of these programmes.
2. That these programmes comprise the following activities :
  - (a) Soil surveys, classification, and research
  - (b) Land capability surveys and classification

## SOIL SCIENCE IN THE CARIBBEAN

- (c) Farm management surveys and research
  - (d) Economic land use classification
  - (e) Specific land utilisation programmes, including soil and water conservation, based on the information provided by the foregoing activities.
3. That the government of each territory appoint a general land improvement administrator or a coordinating committee for land improvement and take other appropriate steps to insure that the above-mentioned five activities are conducted in such a way as to form an integrated Land Improvement Programme within the territory.
  4. That the territorial governments, with the aid of the Caribbean Commission, seek to obtain such technical assistance, through the existing Technical Assistance Programme of the United Nations, the projected Expanded Technical Assistance Programme of the United Nations, technical assistance programmes of governments, and other sources, as they may require in initiating and conducting the Land Improvement Programme.
  5. That, in view of the shortage of personnel in the Caribbean area who have been adequately trained in the activities required for a Land Improvement Programme, the Caribbean Commission and the Food and Agriculture Organisation of the United Nations assist territorial governments in making application to the authorities in charge of the existing Technical Assistance Programme of the United Nations for the allocation of United Nations fellowships for the necessary technical training in these fields of specialists of the Caribbean area.
  6. That the Caribbean Commission appoint to its staff a technical Land Improvement Officer; that this Officer have the duty of obtaining information, through correspondence with appropriate technical officers of the territorial governments, on the status and progress of each of the five activities in their land improvement programmes, compiling and collating this information, and making it available to all territorial governments and the four National Sections of the Commission; and that he also have the duty of obtaining and collecting in a similar manner, and making available to all territorial governments and the four National Sections of the Commission, information on the kinds and amount of technical assistance required by all the governments in initiating and conducting their Land Improvement Programmes.
  7. That arrangements be made through the Caribbean Commission whereby the officers in charge of the land improvement programmes in the various Caribbean territories would correspond and periodically confer

on the administration of these programmes, so as to achieve as much coordination as is desirable and feasible between the Land Improvement Programmes of the various territories and advise the Land Improvement Officer of the Commission on policy in the administration of Land Improvement Programmes; and that these officers should constitute a Land Improvement Advisory Council of the Research Council of the Commission.

8. That the Commission, with the advice of the territorial governments, appoint the following three technical sub-committees of the Land Improvement Advisory Council, suitably representative of the organisations engaged in the Land Improvement Programme in all territories, to advise and assist the Land Improvement Officer of the Commission in collecting and collating information and facilitating its exchange amongst territories and National Sections :
  - (a) A technical committee on soil surveys, classification, and research consisting of specialists engaged in the work.
  - (b) A technical committee on land capability surveys and classification and soil and water conservation.
  - (c) A technical committee on farm management research, economic land use classification, and land utilization programmes.

## PART V

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### GENERAL RECOMMENDATIONS

(34) The Conference, in plenary session, adopted the following recommendations :

1. The delegates to the Conference record their gratitude for the assistance rendered by the many observers, visitors and other persons from several countries and organisations interested in or concerned with the study of tropical soils. These observers, visitors and other persons participated fully in the deliberations, and their individual scientific eminence and collective competence contributed equally to the comprehensiveness of the discussions and to the exchange of technical information covering a wider field than would have been possible without them. The Conference regards such invitations, on the widest possible basis, as essential for all similar technical conferences, and takes this opportunity of emphasising that technical problems and needs know no political boundaries.
2. The Conference, while expressing its appreciation of the many and varied valuable technical papers presented to it, considers that, for future technical conferences, any Preparatory Committee appointed to assist in their preparation should select the scientists who should be invited to prepare papers and the titles of the papers which should be prepared, with a view to reducing their number.
3. The Conference, having given careful consideration to the seminars which have been arranged, is of the opinion that these seminars represent a valuable medium for the dissemination and exchange of pertinent information and in facilitating contacts between scientists in the area and between them and their colleagues outside. It takes the view that such seminars should form an integral part of all future technical conferences, and that participants should be invited to prepare papers for such seminars in advance of the Conference.
4. The Conference considers that the Central Secretariat of the Caribbean Commission should endeavour to publish the papers submitted to the Conference, or, if that is not feasible, should use its good offices with appropriate journals and organisations in the metropolitan countries and/or Caribbean territories with a view to securing the publication of as many of the papers as possible.
5. The Conference records its appreciation of the extensive and valuable field trips arranged for its members, and is of the opinion that similar trips should be included in the programme of all future

technical conferences, to take place, where possible, before the Conference\*.

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Contact is thereby established between the participants of the Conference at an early stage and the process of interchange of information and ideas greatly facilitated. Such field trips also perform the valuable function of making participants acquainted with the problems of the area.



## PART VI

### RESOLUTIONS

(35) The following resolutions were adopted by acclamation by the Conference :

1. The Soils Conference meeting in Puerto Rico wishes to express to the Government of Puerto Rico its grateful appreciation of the courtesies and hospitality extended to its members, and particularly of the arrangements made for their transportation.
2. The Conference wishes to record its warm appreciation of the facilities extended to it by the Chancellor of the University of Puerto Rico, who kindly consented to open the Conference, and by the Acting Director of the Agricultural Experiment Station of the University, in accommodating the Conference, providing office space and meeting rooms, and all local transportation.
3. The Conference wishes to record its appreciation of the facilities extended to it by the Puerto Rico High School of Commerce which placed its dormitories, cafeteria and auditorium at the disposal of members of the Conference.
4. The Conference wishes to pay the warmest tribute to Dr. Juan A. Bonnet, as a result of whose untiring devotion and indefatigable efforts, first as chairman of the Preparatory Committee, and later as chairman of the Conference, a large number of eminent scientists was assembled, a considerable quantity of technical information amassed, and the success of the Conference is largely to be attributed.
5. The Conference wishes to place on record its appreciation of the labours of the members of the Preparatory Committee who were responsible for the arrangement of the scientific programme of the Conference, and expresses the opinion that the appointment of similar Preparatory Committees is an essential prerequisite for all future technical conferences.
6. The Conference places on record its appreciation of the services rendered by the Secretariat staff in enabling the work of the Conference to progress smoothly and successfully.

A P P E N D I X A

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Survey of Existing Conditions

Problems

Recommendations

I. Soil Forming Factors Data

1. Considerable amount of information available on geology (Spencer, Purves, Kugler, etc.)
2. Fair amount known about topography (W.M. Davis). Aerial survey completed by United States authorities during World War II.
3. Considerable information published regarding rainfall and other meteorological matters.
4. Fair amount known about natural vegetation (Beard, etc.)

1. Need of detailed information on clay mineral components of parent rocks and soil materials.
2. Need of detailed topographical maps compiled from aerial survey photographs.
3. Need of recording rain gauges.

1. Increase the staff and facilities of British Caribbean Soil Survey.

II. Standardisation of Soil Survey Methods

1. Detailed field-to-field survey of most of the island carried out by C.F. Charter (1938).

Survey of Existing ConditionsProblemsRecommendations

## II. (Contd.)

2. Profile pit samples analysed for most soil types (Hardy and Rodrigues : I.C.T.A.)

III. Systems of Soil Classification and Mapping

Classification of soils on I.C.T.A. system essentially geological. Charter's system based on pedological principles; stresses derivation of parent materials and their content of calcium carbonate.

IV. Detailed Regional Programme of Soil Survey

Soil survey more or less completed for the agricultural areas (J. Charter, 1938) (See II).

Soil maps urgently needed.

1. Increase the facilities of the British Caribbean Soil Survey.
2. Seek help from Government Cartographers.

V. Survey of Soil Erosion, Conservation, Renovation

No reliable information available or published regarding soil erosion.

Need for systematic surveys.

Increase staff and facilities of British Caribbean Soil Survey.

Survey of Existing Conditions

Problems

Recommendations

VI. Application of Soil Survey  
to Land Utilization

Nothing concrete attempted,  
although land settlements  
have been initiated.

Need for formulation of more  
specific plans for settlement  
of peasants.

1. Formation of committee or ini-  
tiation of discussions.
2. Possibly seek aid from U.S.  
authorities.

BARBADOS

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Survey of Existing Conditions

Problems

Recommendations

I. Soil Forming Factors Data

- |   |   |   |
|---|---|---|
| 1. Considerable amount of geological information available.                                       | Need for information regarding variation in composition of limestone of the different terraces as affected by impurities. | 1. Seek help from analytical chemists, etc. |
| 2. Some topographical data available.   |   |   |
| 3. Abundant meteorological data available.  |   |   |
| 4. Considerable information available on vegetation, both remnant-forest, weeds and native flora. |   |   |

II. Standardisation of Soil Survey Methods

No data available.

III. Systems of Soil Classification and Mapping

No data available.

IV. Detailed Regional Programme of Soil Survey

- |   |  |  |
|---|--|--|
| Rough soil map available. Article on soils already published (Saint, 1934). | Need for detailed soil survey, with especial reference to (a) depth of soil, (b) nature of | 1. Increase staff and facilities of British Caribbean Soil Survey. |
|---|--|--|

Survey of Existing Conditions

Problems

Recommendations

IV. (Contd.)

parent materials, whether lagoon deposits or limestone solution-residues.

2. Seek cooperation of Barbados Dept. of Agriculture.

V. Survey of Soil Erosion, Conservation, Renovation

Some information available regarding soil erosion in the Scotland District.

Need for assessment of soil-losses in the red and black soil areas.

As IV.

VI. Application of Soil Survey to Land Utilisation

Nothing published as far as known.

## A N N E X I

### METHODS OF FIELD SURVEY AND ROUTINE SOIL ANALYSIS IN USE AT THE GOVERNMENT LABORATORY, BARBADOS

By

J.B.D. Robinson, B. Sc., Agric. (Hons.) Agricultural Chemist  
(Department of Science and Agriculture, Barbados)

The methods described are being applied to surface composite soil samples, and such soil samples taken during the course of soil survey and other diagnostic soil investigations.

Field : If the area under investigation is small, random surface soil samples are taken to a depth of 9 inches. Profile pits dug on selected sites are rectangular and approximate to 3 feet by 3 feet wide, and a maximum of 5 feet deep. Profile samples are taken in relation to visual profile characteristics. This may not only vary with soil colour, but, as the soils sampled are all cultivated, with the profile face appearance also, i.e. hydrological features, especially where a "catena" classification into the four Turner soil groups is being undertaken. The samples taken are placed in cotton bags and labelled.

#### References

- Turner, P.E., Report on Development in Sugar Cane Agriculture in Barbados, with special reference to methods of Tillage, Drainage and Contour Cultivation, 1945.
- Turner, P.E., Third report on Development in Sugar Cane Agriculture in Barbados, with special reference to Cultivation and Drainage problems of the four agricultural groups of soils, 1948.

Laboratory Preparation : The samples are spaced out in wooden trays, any large lumps being broken down, and air dried. They are broken down in a wooden mortar and pestle, and sifted through a 2 mm. sieve. Stones are estimated as per cent gravel.

Laboratory Analysis : All analyses carried out on air dry soil which has passed a 2 mm. sieve, unless otherwise stated.

- (i) Reaction : This is measured on an aqueous suspension, 1 part soil : 2.5 parts water, by means of the quinhydrone electrode.

- (ii) Calcium Carbonate Content (free) : This is measured by means of the Collins Calcimeter.
- (iii) Organic Matter : A modification of the Walkey-Black method of estimation is used, whereby the green colour of the oxidised reagent is measured on a spectrophotometer. (This method has recently replaced the previous wet oxidation method)

References

Soil Science, 1948, 65, 181.

Soil Science, 1948, 66, 241.

- (iv) Nitrogen : Nitrogen is determined according to the Kjeldahl method, using 10 grms. soil, 10 grms. potassium sulphate, a crystal of copper sulphate as catalyst, and 30 ml. concentrated N free sulphuric acid.
- (v) Chloride : For this determination 100 grms. of air-dry soil are shaken for 15 minutes with 500 ml. distilled water. The filtrate is titrated with N/35.5 silver nitrate with potassium dichromate as the indicator.
- (vi) Available Phosphate : A new method has recently been adopted. Twenty-five grms. of air-dry soil are extracted with 100 ml. of Morgan's Universal Extracting solution by shaking for 5 minutes and filtering. Measurement is made on a spectrophotometer of the blue colour produced in the presence of phosphate after the addition of molybdate and stannous chloride solutions. This method is both rapid and accurate, and avoids the error of human element in the colour measurement.

Reference

J.C.I., 1946, 65, 208.

- (vii) Available Potash : For the determination of available potash, the same extract is used from the determination of available phosphate. A turbidimetric estimation of the stable cloud formed when potassium reacts with sodium cobaltinitrite in the presence of a glycol-alcohol mixture which gives maximum dispersion, is made with a spectrophotometer. This method is both rapid and accurate.

Reference

J.C.I., 1945, 64, 182.



- (viii) Total exchangeable bases and exchangeable hydrogen : These are determined by the Schollenberger neutral ammonia acetate method, using 25 grms. of soil and 500 ml. of leaching solution. Exchangeable hydrogen ion concentration in an acid soil is then determined by electrometric titration to pH 7. Evaporation of the leachate heating gently in a silica dish for a few minutes, and then for 20 minutes strongly, will give the value on back titration with  $\frac{N}{10}$  caustic soda, for the exchangeable bases. We are thinking of introducing the Barium Chloride Triethanolamine (at pH 8.1) method of analysis of calcareous coral limestone soils.

Reference

Soil Science, 1948, 66, 429.

- (ix) Total base exchange capacity : In addition to the above (viii), this factor can be determined by replacing the adsorbed  $\text{NH}_4^+$  ions in the soil after washing out excess ammonia acetate with neutral 80 per cent. alcohol.

Reference

Soil Science, 1945, 3-7, 13.

Modification in presence of excess manganese oxides.

Analytical Chemistry, 1948, 20, 1121.

Exchangeable calcium is estimated on the residue from (viii) above, after separation and precipitation as the oxalate.

- (x) Mechanical Analysis : The international pipette analysis method is used for determination of the ultimate soil particles, after free treatment with hydrogen peroxide and hydrochloric acid to destroy the aggregate soil structure.

## A N N E X II

### EXISTING CONDITIONS AND PROBLEMS OF SOIL EROSION, SOIL CONSERVATION AND SOIL RENOVATION IN BARBADOS

By

J.B.D. Robinson, B.Sc., Agric. (Hons.) Agricultural  
Chemist (Department of Science and Agriculture, Barbados)

#### Soil Erosion

Before specifying the types of erosion which occur in Barbados, it is necessary, in order to give a clear picture, to mention two facts. One is that there are two distinct soil areas to be considered in relation to erosion, viz., the Scotland soil area on the north east of the island, comprising one-seventh of the total area, and the Coral Limestone soil area covering the remaining six-sevenths of the island's surface. The second is that there is a definite wet season from June - July to the end of November, during which time the great majority of the erosion occurs.

Scotland Area : The soils of this area, which vary from light sands to clays, are generally much more susceptible to erosion than the Coral Limestone soils. The sedimentary deposits are folded and faulted, although the overall elevation is not very great, resulting in extremely undulating hilly land with short steep gradients. The most obvious types of erosion are :

- (i) Severe gulying of cultivated and non cultivated land, resulting more often than not in bare faced dry valleys in the higher parts. This non cultivated land would normally carry a secondary scrub growth if left to fall down naturally, or could be used for re-af-forestation, but, due to over-grazing, is left practically bare, with the results described above.
- (ii) Severe sheet erosion occurs over the cultivated slopes, both soil wash and soil creep, exposing the much less fertile lower layer or subsoils. The traditional system of cultivation, that of cane hold- ing with close drains running directly up and down the slope, has little effect in preventing this during heavy rains, and, as would be expected, severe gulying often results in the up and down hill drains, thus further aggravating the problem.
- (iii) Geological slippage, generally in small patches, occurs to a con- siderable extent over the areas as a direct result of either heavy rains or the diversion of drainage water from a catchment area to a point lower down the slope.

- (iv) Recently a case of severe wind erosion was found in this area. The prevailing wind had been funnelled into the depression on a slope (gradient varying 35 - 40 per cent.) and had moved the soil, fortunately uphill, to the extent of flattening beyond all trace the contour furrows laid down four months previously.
- (v) Main water course erosion during the wet season is of course extremely serious. During the dry months it is possible to see what are virtually small ravines with a trickle of water in the bottom, and a depth below normal land level of anything from 10 to 40 feet, and varying in width to as much as 40 feet, with cultivated cane growing to the edges. During the wet season, these water courses are quite liable to change course.

Coral Limestone Area : The soils vary in clay content from 50 per cent in the black lowland soils to 70 per cent in the red upland soils. It is very noticeable, after heavy rains such as last year (10 inches to 15 inches in a matter of 8 hours), that the black lowland soils are much more susceptible to erosion than the red soils. The land is undulating compared with the Scotland area, and the gradients are not so extreme.

- (i) The major type of erosion sheet washing of the undulating slopes. This brings about the difference in soil depth which can be determined almost anywhere between the top of a slope or hillock, and the bottom of the slope; this, of course, has a major indirect effect on cane yield through the soil moisture factor.
- (ii) Where there is a tendency in the lie of the land for a natural water course, there occur rilling and incipient gulying. In a few cases severe gulying will result.

Emphasis with respect to sheet washing must be placed on soil creep and splash effect, with respect to soil not completely covered down by a crop in the wet season. Many of these soils are free-draining, and only under exceptionally heavy rainfall conditions would there be sheet washing on these soils. (This applies to the red coral limestone soils particularly).

There is a deficiency of windbreaks in the form of trees throughout the island. This deficiency is undesirable for reasons other than soil erosion, of course.

### Soil Conservation

It was not until 1943 that steps were taken in Barbados to control soil erosion, by which time the problem was so urgent that modifications to suit local conditions of existing methods in the form of Contour Cultivation

were adopted by the Department of Agriculture without previous trial. Soils in the coral limestone areas are not considered as a whole deep enough to practice terracing, and the cost is considered prohibitive. There are also problems in connection with field size, transport of cane, etc.

Thus the measures being taken are :

- (i) Contour Cultivation (Coral Limestone soil areas ). Where no drainage problem exists, this is laid down without a fall, the system being based on key contour furrows laid down at an appropriate vertical interval. Where drainage problems exist, one per cent. graded contour systems are laid down.

Where the old Cane Hole system has not been relinquished entirely the result is a system of key contour furrows with cane holes between them, instead of the complete contour system.

A recent survey (November, 1949) of contour cultivation in the coral limestone area revealed that, of the total arable acreage, 2.4 per cent is now under a complete contour system, and 2.5 per cent is under a semi-contour system, i.e., key contour plus cane holes. Assuming that 50 per cent of this area is flat and requires no erosion control measures - this is a very liberal estimate -, still the percentages are only 4.8 and 5.0, respectively.

- (ii) Protection of the lower cultivated land from the water run-off of rocky, shallow soiled sour grass pastures situated on the upper lands in the watershed areas. This is carried out by means of graded contour drains, in the pastures, and diversion ditches on the lower side of these pastures, leading excess water into swallow (suck) holes in the coral rock.
- (iii) Contour Cultivation (Scotland area). Here, due to the steeper gradients (up to 75 per cent) on some cultivated lands, the contour systems have been more severe, with a 2 per cent grade, ensuring that the overall length was not too great. Figures for this area comparable to the coral limestone soils indicate that 28.6 per cent of the cultivated land is under a complete contour system and 6.7 per cent is under semi-contour, i.e., key contour furrows plus cane holes. In areas of geological slippage referred to earlier, where typical symptoms of "slumping" and "flow" are evident, it has not been successful. Unless it works 100 per cent from the start, it has a further tendency to retain moisture resulting in aggravation of the condition. It is proposed now to try a herring bone pattern of drainage with short laterals, graded 4 per cent, and frequent outlet drains.

Soil Renovation

- (i) General soil renovation and rehabilitation have been carried out as routine estate practice. This has consisted of moulding up the "brows", i.e., replacing the soil washed into the bottom of a field or fields, back on to the brow by hand labour. Now, of course, this is both costly and needless where measures of prevention are being taken.
- (ii) In the Scotland area very severe erosion of hill peaks has resulted, because of over-grazing by peasant stock, mostly sheep and goats.

Re-vegetation of these slopes would go a long way towards rehabilitation, as they fall into the land classification group VII of the United States Conservation Service. They will re-vegetate themselves satisfactorily if left alone, or this can be hastened by tree planting.

Before any of this can be carried out on a large scale in Barbados, it will be necessary to control by legislation the movement of man and animal in this area.

- (iii) Around the coast line, wherever waste dune areas or poor waste land subject to severe sea-air blast is situated, plantings of Casuarina have or could be made. It has proved itself an excellent agent in these places for binding together loose soil materials, and for providing shade. On a ten year rotation, the Casuarina provides an income from the firewood harvested by careful rotational cutting.
- (iv) The planting of Casuarina as windbreaks on plantation sour grass pastures is encouraged. When planted 10 feet by 10 feet, they are used by the plantations as a yardstick at grass cutting time.

## BRITISH GUIANA

### Survey of Existing Conditions

### Problems

### Recommendations

#### I. Soil Forming Factors Data

- |  |   |   |
|--|---|---|
| 1. Excellent geological reports and maps of the area (J.B. Harrison; Dept. Geol.). | 1. Need of geological information and maps for <u>southern</u> part.                                | 1. Seek further cooperation from Depts. of Geology and Lands and Mines. |
| 2. Some topographical data available   | 2. More topographical data needed (contours; altitudes).  | 2. Seek further cooperation from Depts. of Geology and Lands and Mines. |
| 3. Rainfall data, etc., available for a few stations, mostly coastal.              | 3. Much more rainfall data needed for interior.   | 3. Seek help from local meteorological authorities.                     |
| 4. Recent report on forest vegetation compiled but not yet published (Fanshawe).   | 4. Intensification of vegetation surveys needed, particularly of undergrowth, as soil-type markers. | 4. Seek further cooperation from Forest Department.                     |

#### II. Standardisation of Soil Survey Methods

Auger and pit method applied to some frontland sugar estates (Chenery: Knowles).

Need for working out soil survey methods for demarcating agriculturally-useful areas.

Increase the staff and facilities of British Caribbean Soil Survey.

#### III. Systems of Soil Classification and Mapping

No final system of classification yet agreed on, nor yet applied. Lithological system so far

Need further field information, both of frontlands and of interior soils, on which to base a classification system.

As II.

<u>Survey of Existing Conditions</u>	<u>Problems</u>	<u>Recommendations</u>
III. (Contd.)		
mostly used for classifying soils of the interior.		
IV. <u>Detailed Regional Programme of Soil Survey</u>		
Not yet considered. Some preliminary work done by F. Hardy, <u>et al.</u> , on frontland and interior soils. C.F. Charter has briefly investigated some interior soils.	Need to extend British Caribbean Soil Survey to allow quick action in regard to local needs, both frontlands and interior. More maps needed.	As II.
V. <u>Survey of Soil Erosion, Conservation, Renovation</u>		
Not much information on record.	Need to assess erosion damage within different type-areas.	Seek help from Depts. of Geology, Forestry and Agriculture.
VI. <u>Application of Soil Survey to Land Utilisation</u>		
Nothing yet attempted.	Need for the formulation of plans for settlements in the interior.	I. As II. 2. Discuss subject with local authorities (e.g. Dept. of Agriculture).

sparse.

4. Natural vegetation (forests) has been investigated in some detail by Forest Department, since the country depends largely on forest products.

## II. Standardisation of Soil Survey Methods

- |  |  |  |
|--|--|--|
| <ol style="list-style-type: none"> <li>1. Profile pit method has been applied in preliminary survey (Hardy, Smart and Rodrigues, 1935).</li> </ol> | <p>Detailed soil survey of specific areas is needed for immediate development plans.</p> | <p>Increase the staff and facilities of the British Caribbean Soil Survey.</p> |
| <ol style="list-style-type: none"> <li>2. Reconnaissance methods applied by Charter (1941).</li> </ol>   |  |  |



<u>Survey of Existing Conditions</u>	<u>Problems</u>	<u>Recommendations</u>
<p>III. <u>Systems of Soil Classification and Mapping</u></p> <p>The system of classification used by Hardy, Smart and Rodrigues (1935) is essentially geological. That used by Charter is based primarily on topography and the permeability of the parent materials of the soils (i.e. on natural drainage). It is essentially agricultural.</p>	<p>Need for revised classification to link up with system applicable to Caribbean Region as a whole.</p>	<p>1. As II. 2. Seek help from U.S. authorities.</p>
<p>IV. <u>Detailed Regional Programme of Soil Survey</u></p> <p>1. Reconnaissance surveys by I.C.T.A. and by Charter have broadly defined the main soil-types.</p> <p>2. No detailed mapping has been yet attempted.</p>	<p>Need for systematic soil survey, especially of areas having immediate agricultural importance.</p>	<p>As III.</p>
<p>V. <u>Survey of Soil Erosion, Conservation, Renovation</u></p> <p>Not much information on record.</p>	<p>Need to assess erosion damage in areas already in agricultural use.</p>	<p>Seek help ies.</p>
<p>VI. <u>Application of Soil Survey to Land Utilisation</u> (See Charter's memoir).</p>	<p>Need for formulation of detailed plans.</p>	<p>Seek help from U.S. authorities.</p>

BRITISH VOLCANIC ARC ISLANDS \*

Survey of Existing Conditions

Problems

Recommendations

I. Soil Forming Factors Data

- |   |   |   |
|---|---|---|
| 1. Fair amount of geological information available (J.B. Harrison; Earle; Macgregor; Anderson and Flitt). | 1. Urgent need of aerial surveys of each and all the islands.                                   | 1. Expedite aerial surveys and the compilation of accurate maps of each of the islands. |
| 2. Some topographic details known (W.M. Davis).   | 2. Urgent need of accurate maps for plotting the available information of soil-forming factors. |   |
| 3. Fair amount of meteorological data published.  | 3. Need for recording rain gauges.  |   |
| 4. Considerable amount of information on forest and second growths (Beard).                               |   |   |

II. Standardisation of Soil Survey Methods

- |  |   |   |
|--|---|---|
| Only reconnaissance survey methods so far applied; profile pit sample. | Need for investigation of methods of detailed soil surveying. | Increase the staff and facilities of British Caribbean Soil Survey. |
|--|---|---|

III. Systems of Soil Classification and Mapping

- |                          |                              |           |
|--------------------------|------------------------------|-----------|
| Classification system so | Need for comparison of soil- | 1. As II. |
|--------------------------|------------------------------|-----------|

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\* Grenada, the Grenadines, St. Vincent, St. Lucia, Dominica, Montserrat, Nevis, St. Kitts.

<u>Survey of Existing Conditions</u>	<u>Problems</u>	<u>Recommendations</u>
<p>III. (Contd.)</p> <p>far applied is merely local and provisional. Main soil-types being studied in field and laboratory.</p>	types with world groups.	2. Seek help from U.S. soil scientists and experts on soil classification.
<p>IV. <u>Detailed Regional Programme of Soil Survey</u></p> <p>Reconnaissance surveys have been made by pit method of all the islands (except Grenadines), with varying degrees of intensity.</p>	Need for detailed soil surveys, and for accurate maps on which to plot the field information.	<p>1. As II.</p> <p>2. Expedite aerial surveys and the compilation of accurate maps on which to plot soil survey data.</p>
<p>V. <u>Survey of Soil Erosion, Conservation, Renovation</u></p> <p>Articles on soil erosion in St. Vincent and Montserrat already published. Fair amount of general information available but not published.</p>	Need for maps onto which all available information may be plotted.	As I, II, III, and IV above.
<p>VI. <u>Application of Soil Survey to Land Utilisation</u></p> <p>Nothing yet specifically attempted.</p>	Need for the elaboration of plans for better land utilisation.	<p>1. Formation of committee or initiation of discussions.</p> <p>2. Seek aid from U.S. authorities.</p>

## FRENCH GUIANA

### Survey of Existing Conditions

### Problems

### Recommendations

#### I. Soil Forming Factors Data

- |  |  |  |
|--|--|--|
| 1. An excellent study of the geology and petrography of French Guiana by B. Choubert.  | Extension of geological prospecting.   | Cooperation of the different scientific organisations engaged in the study of French Guiana.                         |
| 2. Map to the scale of 1/500,000 and sections of the map to the scale of 1/100,000 and 1/50,000 prepared by the National Geographical Institute. This last, coloured, emphasises the difference in vegetation of the elevated portions. Photographic cover of a part of French Guiana. | Aerial cover of the whole of French Guiana to the scale of 1/10,000 or 1/20,000. Preparation of a contour map. | Establishment of a service for the purpose of developing maps and aerial photographs.                                |
| 3. Very few meteorological stations.   | To increase the number of meteorological stations especially in the interior.                                  | Cooperation of the meteorological services with those engaged in soil research.                                      |
| 4. Flora of French Guiana by Fuset Aublet.<br><br>Report on the forest question by P. Béna, not yet edited.  | Survey of soils in relation to vegetation.   | Spécialization of qualified officers for the purpose of carrying out pedological and ecological surveys on the spot. |

Survey of Existing Conditions

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Recommendations

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II. Standardisation of Soil Survey Methods

No work done.

Collate all existing bibliographies making use, in particular, of the latest reports of the Goma Conference (Belgian Congo).

III. Systems of Soil Classification and Mapping

As above.

Use the information furnished by aerial photographs.

IV. Detailed Regional Programme of Soil Survey

No study made.

This work will be undertaken by officers specialising in pedological and ecological surveys, in collaboration with all scientific organisations engaged in soils.

V. Survey of Soil Erosion, Conservation, Renovation

As above.

VI. Application of Soil Survey to Land Utilisation

No study made.

As above.

Revolutionary views must not

Survey of Existing Conditions

Problems

Recommendations

VI. (Contd.)

be feared. The conditions of environment in the tropics being so different from those in temperate regions, a form of agriculture that is typically tropical should result from these surveys.

## GUADELOUPE

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### Survey of Existing Conditions

### Problems

### Recommendations

#### I. Soil Forming Factors Data

- |   |   |  |
|---|---|--|
| 1. Geological information available from Prof. H. Barrabe of Paris (1934 : <u>Bull. Comb. Lig.</u> ) and, for the Soufriere, by Gouault (1946), but no maps.  | Need of more works on geology and particularly for the Central Mountains.   | Increase the staff and facilities of the Geologists and World Physicians (Scientific research)                           |
| 2. Existing topographical map not up to date. Aerial survey photographs available. Topographical information recently undertaken by Topographic Service.  | Need for more topographical information.  | Cooperation of this staff with scientists of the Agronomic Research Centre and Topographers for preliminary soil survey. |
| 3. Climatological data available only for the many stations of sugar cane plantations, but rare for the other districts.  | Need for extension to the middle and higher districts.  | Publication of a meteorological map (Meteorological Service and Agronomic Research).                                     |
| 4. The ecology of vegetation is now well known : H. Stehlé, 1935: <u>Ecology and Plant Geography</u> ; H. and M. Stehlé, F.L. Quentin : <u>Flora</u> (1934-1950); Suppl. <u>Carib. Forester</u> (1945-47). Map of plant | Need for continuation and generalisation of these works for Guadeloupe and Dependencies : St. Martin, St. Bartholomew, Marie-Galante, Les Saintes and Désirade. | Cooperation between Agronomic Research (Botanist), Agriculture and Forestry. Seek appointment of soil survey officer.    |

Survey of Existing Conditions

Problems

Recommendations

I. 4. (Contd.)

associations by H. Stehlé (1936). Plants recognized as biological markers or as "soil type" are listed.

II. Standardisation of Soil Survey Methods

Soil survey methods have been standardized by the Forest/Topography Services: G. Chatelain, P. Béna, Guichon and Huguet.

As I. 4.

III. Systems of Soil Classification and Mapping

Classification of soils is essentially geological.

System based on pedological principles must be applied. For Grande-Terre, Désirade and Marie-Galante, limestone islands, need for knowledge of the content of calcium carbonate for the main soil types. For Guadeloupe and Les Saintes, volcanic islands, need for knowledge of derivation of parent materials and composition.

As I. 1.

IV. Detailed Regional Programme of Soil Survey

1. Programme mentioned in a

Soil survey for agricultural As I. 1.



<u>Survey of Existing Conditions</u>	<u>Problems</u>	<u>Recommendations</u>
IV. 1. (Contd.)		
brief Report by H. Stehlé (1949).	areas is urgently needed. Work in progress by the Forest Service (Huguet) and by the Agronomic Research (Stehlé) since 1949.	As I. 1.
2. Trials begun by Agronomic Research since July, 1949 on disintegrated soils around Prise d'eau.		
V. <u>Survey of Soil Erosion, Conservation, Renovation</u>		
1. No general policy, but "Code Forestier" is in application. Principles of Code must serve as guides.	Need for systematic surveys and legislation regarding land tenure.	As I. 1.
VI. <u>Application of Soil Survey to Land Utilisation</u>		
1. Map of main crops under cultivation available by H. Stehlé (1949) for Guadeloupe and Dependencies.	Need for formulation of plans for settlements and for systems suited to rational economic and ecological conditions.	Appointment of staff and provision of facilities for Soil Survey.
2. Land settlements are in the primary stages.		

## JAMAICA

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### Survey of Existing Conditions

### Problems

### Recommendations

#### I. Soil Forming Factors Data

##### Vegetation

Information about the vegetation factor is limited, and there is very little area left which is still supporting its natural vegetation. Reafforestation has hitherto proceeded at a relatively slow rate, and land which is not now being cultivated is reverting to secondary bush, the character of which is determined by rainfall and the degree of erosion which has taken place.

The demands of a rapidly increasing population have necessitated extensive deforestation. This, coupled with the ruinous practice of clean cultivation of crops - notably banana, ginger and yams - has caused severe truncation of all sloping land, reducing the soil in many instances to what is virtually decomposing parent material.

There has been no ecological survey of the island, and there is no exact knowledge of the actual sequence of the regeneration of vegetation on abandoned land.

## Survey of Existing Conditions

## Problems

## Recommendations

### I. (Contd.)

#### Climate

The mean annual temperature varies from around 57°F at 7,000 feet to 78°F at sea level, and total annual rainfall varies from under 30 inches on the southern coastal plains to well in excess of 200 inches in parts of the Blue Mountain Range. In the absence of protective covering, run-off is excessive, and the actual quantity of water percolating through the soil is small, even on the almost horizontal alluvial plains with soils of high infiltration capacities and permeability.

The high rainfall assists greatly in the soil destruction or truncation process - so much so, that it is almost impossible to get a mature profile developed. In the lower rainfall areas, considerable upward movement of water exists in the surface soil, and the rainfall effect is modified by evaporation.

Lack of adequate data on evaporation, run-off, percolation, etc.

## Survey of Existing Conditions

## Problems

## Recommendations

### I. (Contd.)

#### Topography

On the older geological formations, the topography is extremely broken. Sedentary soils are rare, and confined to small areas of Forest Reserve in the Blue Mountains and the soils derived from Eocene limestone which have remained relatively undisturbed. Over large areas of the older shales, conglomerates and granodiorites, the soil represents the decomposing parent material and are either immature or have been rendered seemingly immature through severe truncation. For this reason, it would appear necessary to classify the soils on a lithological basis, with the exception of the small area of true laterite (derived from serpentine), and soils developed under undisturbed forest.

There has been no lithological survey of the island, and there is pressing need for a geological survey, paying special attention to lithology as distinct from sequence and economic geology.

1. Soils derived from stratified shales and sandstones - the Richmond Series of Hill - are acid or alkaline in reaction, depending on whether the origi-

Survey of Existing Conditions

Problems

Recommendations

I. 1. (Contd.)

al parent material was calcareous or not. The distribution of acid and alkaline soils so derived. does not appear to be related to areas of high or low rainfall.

2. Rendzinas are formed in the high rainfall districts of Portland as well as in the low rainfall belt of St. Mary and St. Ann. Rendzina formation appears to be governed by the soft nature of the parent limestone.

3. In Manchester, St. Elizabeth and St. Ann, bauxitic soils rest on Eocene limestone, whereas apparently similar soils derived from the same white limestone formations in the Montpelier area of St. James are not bauxitic. The differences in soil formation may be due to the different chemical composition of the impurities in the original limestone.

4. The red limestone soils of Manchester - variously

Lack of fundamental data on the scientific characterisation of

Proposed soil survey on a West Indian basis should be expe-

## Survey of Existing Conditions

## Problems

## Recommendations

### I. 4. (Contd.)

called terra rossa, laterite, bauxite - are not soils in the true sense or geological deposits. No zones of elluviation or illuviation occur, and chemical analyses indicate that the composition of the profile remains remarkably constant with depth. These soils are probably not laterite but lithosols, with bauxite as the parent material.

Two main kinds of bauxite soils are distinguished - one deep red and the other yellow-brown in colour. The differences in colour are attributed to the different degrees of hydration of iron oxides present. The distribution of the two types bears no obvious relationship to rainfall distribution, and pedologically the two soils would be grouped together. Distinct properties are associated with the two types in the field - the deep red soils are lacking in available phosphate and respond to applications of

soils. The primary need is for a detailed soil survey of agricultural stations and other experiment sites, so that field experiments can be properly located with respect to soil type.

dited, and future recommendations should be based on this.

Survey of Existing Conditions

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SOIL SCIENCE IN THE CARIBBEAN

I. 4. (Contd.)

phosphate fertiliser, whereas there is no response to phosphate on the yellow soils.

Soils of limestone origin are the dominant soil types.

So far as is known, there are no examples in Jamaica where the same type of soil has been derived from different parent material. Pedological agencies are of secondary importance, the controlling factor being the great differences due to different geological parents.

Geological survey with limited objective is now in progress.

II. Standardisation of Soil Survey Methods

No data available.

III. Systems of Soil Classification and Mapping

No data available.

Survey of Existing Conditions

Problems

Recommendations

IV. Detailed Regional Programme of Soil Survey

No information available.

V. Survey of Soil Erosion, Conservation, Renovation

(a) Soil Erosion

Erosion continues unchecked over a considerable portion of the arable area of Jamaica. Very little area still supporting its natural vegetation remains. Indiscriminate clearing of lands in the mountain catchments of rivers causes severe flood damage during heavy rains with very rapid run-off of water. Sheet erosion in varying degrees is almost universal.

On soils derived from hard White Limestone, erosion is not as prevalent, because rain water percolates quickly. On this geological formation, however, new soil is formed very slowly from the underlying material, and loss of top soil is very serious, because the organic matter is confined to the shallow surface lay-

Great difficulty experienced in the rehabilitation of crops due to severe deterioration of soils as a result of erosion and accompanying factors.



Survey of Existing Conditions

Problems

Recommendations

V. (a) (Contd.)

ers. Soils derived from Yellow or Soft Limestone are heavier and less porous, and erode more rapidly, to expose marly subsoil which does not weather rapidly. The most widely cultivated soils are the Carbonaceous shales and Trappean shales - the main banana soils. They are mostly heavy, need drainage and erode very quickly. The parent material is quick weathering. The Conglomerates and metamorphosed shales of the Blue Mountain range provide lighter and freer draining soils. Due to steep slopes and clean cultivation, serious erosion has taken place. On the Granodiorite soils erosion has reduced the area into a series of steep-sided, knife-edged ridges now mostly abandoned to secondary scrub.

For the last 45 years, banana, cultivated cleanly and with frequent

Survey of Existing Conditions

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Recommendations

V. (a) (Contd.)

drainage trenches, has been responsible for the greatly accelerated erosion of thousands of acres of land in Jamaica.

As a result of the demands of the rapidly increasing population for land, the system of shifting cultivation has broken down.

Over many areas, over grazing has caused the land to be exposed and compacted by trampling. This has greatly accentuated sheet erosion.

(b) Soil Conservation

It is estimated that, since 1945, approximately 10,000 acres have been soil-conserved on estates and 3,000 acres on small holdings.

There is no Soil Conservation Service as such, but the method adopted is to introduce latent compulsion into various rehabilitation and devel-

1. Lack of consciousness of the seriousness of the problem.
2. Lack of funds.
3. There is a shortage of staff.
4. Lack of knowledge regarding the rate at which erosion occurs on the various soil types and under the varying climatic conditions. No experimental work in this con-

1. Continued education in Soil Conservation methods.
2. Development of cooperative action by farmers and Government.
3. Methods of soil conservation that have a direct appeal to the farmer should be evolved.

Survey of Existing ConditionsProblemsRecommendations

## V. (b) (Contd.)

opment schemes, by making grants and allowances conditional on the adoption of proper soil conservation measures. There are 67 Agricultural Instructors in the Extension Service but soil conservation is only one of several duties of the staff.

Investigational work on the agricultural stations is concerned with

- (1) testing of different plants as barriers - whether the barrier crop should be dual purpose or specific;
- (2) observations on the different methods of soil conservation.

(c) Soil Renovation

- (1) Pasture Improvement. It is estimated that 32 per cent of the total land area is in grass - 20 per cent in commons and woodland grass, 9 per cent in Guinea

Basic problem is the building up of organic matter and the improvement of structure of soils that have been properly conserved.

1. The resting of steep slopes from cultivation.
2. The provision of an adequate protective cover on uncultivated land.

Survey of Existing Conditions

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V. (c) (i) (Contd.)

grass (Panicum maximum), and 3 per cent in fodder grasses. The rapid expansion of the livestock industry now taking place is a very promising method of soil renovation - protective grass cover is rendered economic and the policy of fostering rotational farming with grass is being encouraged.

The chief grasses and legumes of the island have been listed, and investigational work on pasture improvement is being pursued, designed to gain information on

- (1) the seasonal yields and nutritive composition of "commons" grasses and of tall tropical fodder grasses in different parts of the island;
- (2) the possibility of increasing both the bulk and nutritive value of pastures through the use of fertilisers;

3. The adoption of proper soil conservation measures on cultivated land.
4. The continued fostering of grass leys in rotational farming.
5. The continuance of investigational work on pasture improvement.

Survey of Existing Conditions

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V. (c) (i) (Contd.)

- (3) the carrying capacity of the different types of pastures, and improvement by controlled grazing and management, including the use of artificial fertilisers.

The Revolving Herd Scheme and the Dairy Assistance Trust, are both designed to aid soil renovation through livestock. Prerequisites for assistance under the schemes are the establishment of proper soil conservation measures, and the planting of 1 acre of fodder grass per cow.

- (ii) Afforestation. It is estimated that 33 per cent of the total land area is in woodland. The Forest Department has 14 projects for re-planting, distributed over the island. To date, 4,600 acres have been planted up. The objective is to plant

The main problem is to determine the most suitable species for the different ecological areas of the island.

In the Blue Mountain area, there is a specific problem of finding a suitable species for establishment under Guinea grass.

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V. (c) (ii) (Contd.)

500 acres per annum.

In the central mountains, a block of 1,000 acres is being reforested as an anti-erosion measure. There are 5 central nurseries, and the Forest Department can distribute up to half a million trees per annum. There is a high percentage of forest land privately owned, and every encouragement is given to reforestation.

(iii) Crop Rehabilitation. A basic feature of several crop rehabilitation and development schemes is the stress laid on the adoption of proper soil conservation measures. Latent compulsion is introduced by specifying that soil conservation is a prerequisite for assistance in the case of

1. The Coffee Rehabilitation Scheme.
2. The Coconut Rehabilitation

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Recommendations

V. (c) (iii) (Contd.)

tion Scheme.

3. The All-Island Banana Growers' Association Fertiliser Scheme.
4. The Citrus Development Scheme.

The Farm Improvement Scheme provides assistance for land clearing, soil conservation, farm buildings, water supplies and applications of lime and phosphate, where necessary. The policy is to encourage the development of mixed husbandry with livestock as the basis of building up soil fertility.

## MARTINIQUE

### Survey of Existing Conditions

### Problems

### Recommendations

#### I. Soil Forming Factors Data

- |   |   |   |
|---|---|---|
| 1. Geological information available from Prof. A. Lacroix of Paris (1902-1940) and Giraud (1905). Several books (about Mount Pelée in particular) and articles on local geology published, with some sketch maps.               | Need of comprehensive and complete treatise, with detailed maps after new geological information.   | Organization of soil survey for all French territories, including Martinique.           |
| 2. Fair topographical map available : Heumier, Prof. of Geology in Paris and Grignon. Aerial survey photographs available.  | Need for more accurate topographical information and of detailed topographical maps, compiled from aerial survey photographs now available. | Cooperation between Forestry, Agronomic Department and Topographers of the Island.      |
| 3. Much climatological data available principally for districts of sugar cane plantations and for Mount Pelée, by the Meteorological Office of Fort-de-France and by H. Stehlé in <u>Caribbean Forester</u> (Suppl. 1945-1947). | Need for a good and up-to-date map according to these records.  | Publication of available map (Meteorological Service and Agronomic Research).           |
| 4. Vegetation now well known: H. Stehlé, "Esquisse des Associations Vegetales" ( <u>Bull. Agr.</u> , Fort-de-France, 1937) and <u>Descriptive Flora</u> (1938-50). Map  | Need for more information on vegetation requirements as "biological indicators."  | Appointment of soil survey officer and cooperation with Director of Agronomic Research. |

MARTINIQUE



Survey of Existing Conditions

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Recommendations

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.I..4. (Contd.)

on Plants and Plant Science in Latin America (Waltham, 1945) by H. Stehlé. Relationship with soil is indicated.

II. Standardisation of Soil Survey Methods

Soil survey methods have been standardised by the Forest and Topography Services : D. Kervegant, H. Stehlé and A. Sobesky.

As I. 4.

III. Systems of Soil Classification and Mapping

Classification of soils is essentially geological and provisional

Application of a system based on pedological principles (Hardy, Charter)

IV. Detailed Regional Programme of Soil Survey

Programme mentioned in a Report by D. Blanche and H. Stehlé, 1946 (brief résumé in Caribbean Commission Monthly Information Bulletin, Oct., 1949).

Soil survey for agricultural and forestal areas is urgently needed.

As I. 1.

V. Survey of Soil Erosion, Conservation, Renovation

No general policy for soil Need for systematic surveys,

As I. 1.

SOIL SCIENCE IN THE CARIBBEAN

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Recommendations

V. (Contd.)

conservation yet in operation, but application of "Code Forestier" must serve for basic principles.

land allocation policy and legislation regarding land tenure.

VI. Application of Soil Survey to Land Utilisation

1. Map of main crops under cultivation available, by A. Sobesky (1934-1945).

Need for economical and ecological systems and for their application.

Appointment of staff and provision of facilities for soil survey.

2. No land settlements or land utilisation in accordance with a rational soil survey.

NETHERLANDS WEST INDIES

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Survey of Existing Conditions

Problems

Recommendations

I. Soil Forming Factors Data

1. Excellent geological publications and maps. A complete bibliography has been published in Overzicht van de Geologische en Mynbouwkundige keunis der Nederlandse Antillen (Survey of the Geology and Mining of the Netherlands Antilles), Royal Institute for the Indies, Amsterdam, 1949, with a summary in English, by J.H. Westerman.

St. Martin has been mapped recently by geologists of Princeton University; publication and map will be published in 1951. For the volcanic islands of Saba and St. Eustatius, detailed maps are not available.

2. Excellent topographical maps available for Leeward group - Curacao, Aruba and Bonaire - and for St. Martin (Dutch part) and St. Eustatius. Hydrographic map of Saba.

Need of information on minor geological details.

Need of detailed information and petrographical maps of Saba and St. Eustatius.

Need of an aerial survey.

Seek further cooperation from Netherlands Universities.

Aerial survey is being planned by the Government.

Survey of Existing Conditions

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Recommendations

I. (Contd.)

3. Climatological data available

Need for extended recording.

4. Fair amount of information on vegetation (Boldingh, 1909 for Windward Group - St. Martin, Saba, St. Eustatius -, and 1914 for Leeward Group).

Need for more information on vegetation types.

The Scientific Foundation for Surinam and Curacao, Holland, plans to compile a new flora.

II. Standardisation of Soil Survey Methods

None.

Need for investigation of methods of soil surveying.

Seek help from Netherlands Soil scientists.

III. Systems of Soil Classification and Mapping

Classification system so far applied still incomplete. Main soil types have been studied in laboratory, Amsterdam (R. Hamilton & W.M. Sessler, 1945), as well as by H.A. Ballou, Trinidad, 1934.

Need for further comparison of soil types and soil mapping with other Caribbean Islands.

As II.

IV. Detailed Regional Programme of Soil Survey

Still lacking.

Need for detailed soil surveys in arable areas.

As II. A complete soil survey of the three islands of the Windward Group is being organized for

<u>Survey of Existing Conditions</u>	<u>Problems</u>	<u>Recommendations</u>
IV. (Contd.)		1950-51 by the Foundation for Development and Welfare in the Netherlands Antilles.
V. <u>Survey of Soil Erosion, Conservation, Renovation</u>		
Some general information available in reports, but not published.	Need for survey.	Seek help from local departments. For the Windward Group see IV.
VI. <u>Application of Soil Survey to Land Utilisation</u>		
Nothing yet specifically attempted.	Need for specific plans for settlement of farming communities.	Seek help from local and Netherlands agencies.

PUERTO RICO

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Survey of Existing Conditions

Recommendations

I. Soil Forming Factors Data

1. Climate

(a) Rainfall

Data on local climate are available through the Weather Bureau of the United States Department of Commerce. Detailed records have been kept at numerous stations throughout the Island over a long period of years. Maps showing monthly and annual distribution of rainfall are available.

1. Continuation of collection of statistics to provide current records.
2. More stations if complete statistics are to be obtained.
3. Collection of local data to ascertain the relation between microclimate and soil variability within generalized climatic belts.
4. Measurements of rainfall intensity.

(b) Temperature

Idem.

Idem. Also maintenance of maximum and minimum temperature records, particularly in the interior.

(c) Evaporation

Two stations, one at San Juan in the north, and one at Mayaguez in the west, are maintained by the Weather Bureau, and one by the Soil Conservation Service Research, at Central Aguirre in southern Puerto Rico.

Further stations, particularly in arid and semi-arid areas.

## Survey of Existing Conditions

## Recommendations

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### I. 1. (Contd.)

#### (d) Relative humidity

Records are available for San Juan for a number of years. Central Aguirre recently started to collect similar data.

Maintenance of more records over the Island, at least in about 10 selected stations.

#### (e) Wind

Limited data available only for the three above stations. Idem.

### 2. Organisms

#### (a) Flora

Preliminary ecological work has been done by Cook and Gleason.

1. Further study of the relationship between soil and plant development.
2. Investigation of the role of bacteria, fungi, actinomyces and other organisms in soil genesis.

#### (b) Fauna

No specific studies conducted.

Thorough research on the soil forming activities of ants, white grubs, earth-worms, crabs, and other macroanimals, and investigation of the effect of the microfauna.

### 3. Relief

Topographic maps of the Island have been published on a scale of 1:10,000, and are available through the Insular Department of the Interior. The role of relief as a

Studies on the modifying effect of relief variation on climate and the effect of exposures on soil climate and on crop growth.

## Survey of Existing Conditions

### I. 3. (Contd.)

pedogenic factor has been pointed out in some soil associations.

#### 4. Parent material

The Island has been divided into seven regions whose geologic features have been studied. Reports are available for each. A comprehensive report regarding the geology of the Island as a whole has been published. The ground water resources have been studied.

#### 5. Time

Observations have been made regarding the rapid rate at which soil formation proceeds under Puerto Rican conditions.

1. More research as to the role of parent material in tropical soil genesis.
2. Investigation of the weathering of the different minerals.

Quantitative measurements should be made. The time required for soil renovation must be ascertained under different environmental conditions.

## II. Standardisation of Soil Survey Methods

### 1. Field methods

A survey of the whole Island was completed and published in 1942 by the U.S.D.A. in cooperation with the University of P.R. Agricultural Experiment Station. Maps on the scale of 1:50,000 are available. Infiltration rates of more than 90 soil types have been determined, although not published.

Infiltration studies should be completed, including all important agricultural areas.



II. (Contd.)

2. Laboratory methods

(a) Physical measurements

Textural studies have been made on most soils. Limited data available on soil structure. Limited mineralogical analysis of soils has been done in the past for lateritic soils. Studies of x-ray patterns and petrographic analyses are now under way for a large number of soils. Moisture studies have been mostly limited to standard gravimetric determinations of field moisture content. Better techniques are under consideration. Preliminary studies of the whole moisture range in surface soils have been conducted, but not yet published. Water retention capacity and water transmission power of soils are under study.

1. More research on physical properties of soils for their proper characterization.
2. Structural studies be conducted.
3. Investigation of soil mineralogy, particularly as to the relation of clay minerals to the sand and silt fractions under different environmental conditions.
4. Contact phenomena between the coarser fractions of soils and the clay minerals as a means of releasing plant nutrients from relative insoluble material should be considered similar to the work of Marshall and Graham (Soil Science, 49, 277-281, 1940).
5. Determination of particular types of clay minerals in highly weathered tropical soils.
6. Determination of the water supplying power of different soil types.
7. Further study of soil moisture-plant relationship.

(b) Chemical measurements

Complete chemical data for the surface

1. More data with respect to the content of

## Survey of Existing Conditions

## Recommendations

### II. 2. (b) (Contd.)

layer of a large number of soils are available. Considerable data on acidity and organic matter are also available. Data have been collected on exchange capacity and exchangeable bases of Puerto Rican soil, but have not yet been published. Determinations of available and total phosphoric acid and total silica have been reported. Preliminary work with boron has been conducted. Plant analysis and foliar diagnosis as indexes of the fertility of the soil are receiving much attention. Methods are being studied for preliminary work with minor elements.

minor elements in soils, such as copper, cobalt, iodine, fluorine, etc.

2. Correlation between foliar diagnosis, soil analysis, and crop yields.

### (c) Microbiological determinations

Nitrification rates have been determined for soils in northern Puerto Rico.

1. Considerable expansion of investigations of soil microbiology.

2. A microbiological survey.

## III. System of Soil Classification and Mapping

### 1. Textural classification

Soils have been grouped into several classes according to particle size in the surface layer.

Determinations of free sesquioxides to know what is their proportion in the clay fraction.

### 2. Topographic classification

8 physiographic groups have been set.

Studies to determine fitness of soil areas for mechanization on basis of their topography.

III. (Contd.)

3. Geologic classification

Soils have been grouped according to their geologic origin.

Use of mineralogical data as criteria for classification.

4. Productivity rating

Soils have been grouped according to their productive capacity for individual crops. A general rating has also been established.

More detailed data for specific areas.

5. Great soil groups

22 of the great soil groups of the world have been mapped in Puerto Rico. A report with maps has been published. The soils are grouped into 117 series comprising 358 types and phases.

Considerable research needed in soil systematics. The soils classed as podzolic and chernozem should be investigated and perhaps renamed. Lateritic soils should be regrouped in view of new knowledge.

6. Land utilisation classes

The Soil Conservation Service has grouped the land into 8 utilization classes. This classification is based upon adaptation of the land to cultivation and the required conservation practices.

See information for IV.

IV. Survey of Soil Erosion, Conservation Renovation

1. Land Capabilities Determination and Utilization Classes

Land capability tables have been prepared or are being prepared for the 19 soil conservation districts in Puerto Rico and the

These tables are dynamic and are subject to revision as more information is gained in soil studies such as permeability, available moisture

## Survey of Existing Conditions

## Recommendations

### IV. 1. (Contd.)

#### U.S. Virgin Islands.

These tables were prepared in accordance with the "Guide for Soil Conservation Surveys" prepared by the U.S. Soil Conservation Service.

capacity, inherent fertility, etc.

Further research in developing legumes grasses and tree crops for steep slopes unsuitable for cultivation.

### 2. Problem Areas in Soil Conservation

A problem area map including Puerto Rico and the U.S. Virgin Islands was prepared as a part of the Soil Conservation Problem Area Map of the United States which is being prepared by the Soil Conservation Service.

No research is needed, but a more detailed map of each of the soil conservation districts of a scale of 4" to the mile will give a better picture of the conservation needs for these problem areas.

The island of Puerto Rico was divided in two main physiographic regions, first, the Central Mountainous Area and Valleys, and second the Bordering Coastal Plain Area. Each of these was broken down into soil conservation problem areas differentiated on the basis of major differences in soils topography and climate. These were further broken into land resources units, each of which has a comparable pattern of soil, slope, erosion, climatic conditions, and conservation problem.

Similar divisions were made in the land area of the Virgin Islands.

IV. (Contd.)

3. Soil Conservation Practices (Adaptation and Development of New Techniques)

Most of the soil conservation practices now being applied in Puerto Rico and the U.S. Virgin Islands have been adapted from practices already in use in the Continental U.S. and proved to be of practical and effective value. Among some of the more important practices are : contour farming, cover cropping, rotation stubble mulching, pasture improvement and management, wildlife area improvement, woodland, farm and fish ponds, irrigation, field windbreaks, water disposal areas and modified drainage - type terraces.

In addition to the above, other practices have been developed and adapted to conditions in Puerto Rico. Among these may be listed : slope-reduction and development of bench terraces through the use of vegetative and rock barriers, and individual terraces for coffee and fruit trees.

V. Application of Soil Survey to Land Utilization

1. Crop adaptability

Sugar cane, coffee, and other crops are being grown in soils to which they are best adapted in most cases.

1. Additional information and research in rainfall and run-off studies, pasture improvement and management, irrigation and drainage, crop rotations, windbreaks, and farm and fish ponds.
2. More information in determining vertical intervals for terrace construction, the effect of stubble mulching in tobacco farming and the value of individual terrace as it affects the root development, tree growth, and yield of established coffee trees.

Investigation of (1) potentialities of soils for the production of other crops; (2) the possibility of increasing production of low yielding crops.

Survey of Existing Conditions

Recommendations

V. (Contd.)

2. Establishment of irrigation and drainage projects

Soil studies conducted in the Lajas valley and in the Coamo area have shown that nearly 40,000 acres of land could be profitably irrigated. Drainage problems in these areas have been studied.

As available water may, in some cases, be a limiting factor in humid areas, irrigation studies should be extended also to these areas where crop production must be assured. Spacing and depth of drains require further study.

3. Economic land classification

Studies conducted in the Lajas valley. Preliminary work done in the Caguas region.

Further work to complete the land classification for the whole Island.

4. Geographic land classification

Detailed studies of land utilization in relation to physical land conditions are under way, sponsored by the University of Puerto Rico and the Puerto Rico Planning Board.

Completion of this work.

5. Classification for assessment purposes

A classification of rural lands for evaluation of property on basis of its actual value is under way, and may be finished by December, 1950.

Periodic revisions of certain areas.

6. Soil conservation

Farm planning on basis of soil conservation survey work in more than 3,479 farms. Nearly 244,479 acres are under conserva-

Extension of these activities to cover all problem areas.

Survey of Existing Conditions

Recommendations

V. 6. (Contd.)

tion programmes.

7. Soil reclamation

(a) Organic soils

Plans are under way for the reclamation of a large area of muck soils in northern Puerto Rico where high water table is the limiting factor for crop production. Harmful salt content is also a problem in some areas.

Research on (1) regulation of water table depths on crop yields, (2) fertility and salinity problems.

(b) Saline soils

Preliminary attempts to reclaim with sulphur and gypsum have not been successful, probably due to high magnesium waters used.

Reclamation experiments with chemicals should be repeated with fresh waters. The adaptation of rice to these areas should be investigated.

A N N E X I

SOIL AND WATER CONSERVATION PRACTICES IN PUERTO RICO,  
DECEMBER 31, 1949

Practices	Unit	Planned to date	Applied to date <sup>(1)</sup>
Contour farming	Acres	85,313	23,923
Cover cropping	Acres	941	203
Stubble mulching	Acres	95,200	59,598
Pasture improvement	Acres	78,266	43,309
Seeding of pasture	Acres	31,160	10,367
Wildlife area improvement	Acres	1,966	1,621
Woodland management	Acres	39,185	18,081
Tree planting	Acres	11,271	4,308
Farm ponds	No.	72	39
Terraces	Miles	21,282	4,880
Field diversions	Miles	172	90
Farm drainage	Acres	13,820	5,500
Irrigation land preparation	Acres	7,941	2,086
Improved water application	Acres	1,651	220
Crop rotation	Acres	41,170	24,227
Kudzu	Acres	1,228	589
Perennial grasses	Acres	6,950	4,107

(1) It is estimated that application of the planned practices will be completed during the following five years.



## A N N E X 2

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### AIDS USED IN INTERPRETING SOILS DATA AT THE UNIVERSITY OF PUERTO RICO

By

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Assistant Soil Technologist, Agricultural  
Experiment Station, University of Puerto Rico

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#### INTRODUCTION

The interpretation of research data is always one of the problems that has to be confronted by the investigator, perhaps the most important one. Various workers subject their data to various interpretations. The interpretations suggested in this paper are being used at the Agricultural Experiment Station of the University of Puerto Rico. It is hoped that they can be considered as a basis for the standardization of the methods of interpreting soils data in the Caribbean area.

Some of these guides have been developed by us. Others have been adapted from workers in other regions. The establishment of significant limits for the interpretation of field and laboratory data in the Caribbean will probably help to a better understanding of the soil problems of the region.

#### INTERPRETATION OF FIELD DATA

##### 1. Profile depth

Inches to rock or impervious layer	Classification
~ 2	very shallow
2-10	shallow
10-20	medium
20-36	moderately deep
36-60	deep
· 60	very deep

2. Drainage

Depth of mottling in inches	Classification
< 2	very poor drainage
2-10	poor drainage
10-20	imperfect drainage
20-36	moderately good drainage
36-60	good drainage
> 60	excessive drainage

3. Infiltration

(a) Moist soil

Inches of water per hour	Classification
< 0.1	very slow
0.1- 0.5	slow
0.5- 2.0	moderate
2.0- 5.0	moderately rapid
5.0-10.0	rapid
> 10.0	very rapid

(b) Wet soil

Inches of water per hour	Classification
< 0.01	very slow
0.01-0.2	slow
0.2 -0.5	moderate
0.5 -0.8	moderately rapid
0.8 -2.5	rapid
> 2.5	very rapid

## 4. Degree of erosion

## Soil removed

0	n
< 25% topsoil	s
25-75 topsoil	n
75 or more topsoil, or all topsoil and less than 25% topsoil	n
All topsoil and 25-75% subsoil	s
All topsoil and 75% or more subsoil	v

Gullies are recognized as a separate type present a definite control problem by the sified into shallow and deep gullies.

INTERPRETATION OF LABORA

## 1. Texture

See chart. Notice that the "clay" group particles below 2 microns. Sands must upper limit of silt separate.

## 2. Permeability

Inches of water per  
hour

< .05
0.05-.20
0.20-.80
0.80-2.50
2.50-5.00
5.00-10.00
> 10.00

## 3. Available water

## Inches of water

< 1
1-3
3-6
6-9
9-12
> 12

## 4. Conductivity values

## (a) Salinity

Mhos. $\times 10^{-5}$	Status
< 100	no salinity
100-200	slight salinity
200-400	moderate salinity
400-800	moderately severe salinity
800-1500	severe salinity
> 1500	very severe salinity

## (b) Available nutrients

Mhos. $\times 10^{-5}$	Status
< 15	very low
15-50	low
50-100	medium
100-150	high
> 150	very high

## 5. Reaction

pH	Category
< 4.0	very strongly acid plus
4.0-5.0	very strongly acid
5.0-5.5	strongly acid
5.5-6.0	medium acid
6.0-6.5	slightly acid
6.5-7.0	neutral
7.0-7.5	very lightly alkaline
7.5-8.0	alkaline
8.5-9.0	strongly alkaline
> 9.0	very strongly alkaline

## 6. Lime requirement

Tons of $\text{CaCO}_3$ /acre	Classification
> 6	high
4-6	moderately high
2-4	medium
1-2	moderately low
$\frac{1}{2}$ -1	low
0- $\frac{1}{2}$	very low

## 7. Total bases

CaCO <sub>3</sub> equivalent lbs/acre	Classification
< 500	too low
500-5000	low
5000-10,000	moderately low
10,000-25,000	moderately high
25,000-50,000	high
> 50,000	too high

## 8. Cation exchange capacity

.m.c./100 grams of soil	Classification
< 5	very low
5-10	low
10-15	moderately low
15-20	moderately high
20-30	high
> 30	very high

9. Available P<sub>2</sub>O<sub>5</sub>

Lbs. P <sub>2</sub> O <sub>5</sub> /acre	Classification
< 10	very low
10-25	low
25-50	moderately low
50-100	moderately high
100-200	high
> 200	very high

## 10. Potash exchangeable with neutral salt

Lbs. K <sub>2</sub> O/acre	Classification
< 25	very low
25-75	low
75-150	moderately low
150-200	moderately high
200-400	high
> 400	very high

11. Organic matter content

Clayey soil	Sandy soil	Classification
> 6.0	> 3.0	very high
4.5-6.0	2-3	high
3.0-4.5	1-2	medium high
2.0-3.0	0.5-1	moderate
1.0-2.0	0.2-0.5	low
< 1.0	0.2	very low

12. Nitrification rate<sup>1</sup>

mgn. NO <sub>3</sub>	Classification
> 30	very good
20-30	good
15-20	moderate
10-15	moderately low
5-10	low
< 5	very low

13. Nitrogen (Hardy's scheme)

<u>Per cent total nitrogen</u>		
Sands and loams	Silts and clays	Nitrogen status
0.45-0.35	0.60-0.50	very high
0.35-0.30	0.50-0.40	high
0.30-0.25	0.40-0.30	fairly high
0.25-0.20	0.30-0.25	medium high
0.20-0.15	0.25-0.20	medium
0.15-0.10	0.20-0.10	medium low
0.10-0.05	0.10-0.05	low
0.05	0.05	very low

14. Effect of ratio of available calcium to sodium on sugarcane growth.

Ratio	Rating
3:1	unfavourable
15:1	favourable

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Basils : 30 mgn. of nitrogen as ammonium sulphate / 200 mgn. CaCO<sub>3</sub>.

## A N N E X 3

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### FIELD METHODS OF SOIL SURVEY USED IN PUERTO RICO

By

Dr. J.A. Bonnet, Head, and Dr. M.A. Lugo López, Assistant  
Soil Technologist, Agricultural Experiment Station,  
University of Puerto Rico

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#### I. Basic soil survey (U.S.D.A. Soil Survey Division)

Mapping soil types according to logical, natural system of classification. Scale 1:50,000 or 1" = 4166' (1 sq. in. = 400 acres). Soil examination according to the following criteria (5, 8)\* :

##### 1. General features

- a. topographic position
- b. drainage
- c. parent material
- d. native vegetation
- e. apparent productivity
- f. erosion
- g. crops produced
- h. presence of rocks
- i. stoniness

##### 2. Profile observations

- a. arrangement and thickness of soil layers
- b. number of horizons
- c. colour - Munsell colour standard chart
- d. texture - "feel" method
- e. structure
- f. consistency
- g. organic matter content
- h. roots
- i. cracks
- j. free lime - dilute HCl
- k. pH value - Hellige's-Truog kit
- l. concretions
- m. salinity - conductivity bridge

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\* Numbers in parenthesis refer to literature cited.

## II. Conservation survey

Mapping units which may include one or more soil series as basis for farm planning according to soil conservation practices. Scale 1:15,840 or 1" = 1,320' (1 sq. in. = 40 acres).

Consider :

### 1. Soil

- a. effective depth
- b. texture of surface
- c. permeability
- d. available moisture capacity
- e. reaction, free lime
- f. natural drainage
- g. inherent fertility
- h. organic matter content
- i. underlying or parent material

### 2. Slope

Slope classes depending on soils, climate, land use.

### 3. Erosion

Erosion classes depending on degree of damage.

### 4. Land use

5. Special features such as wetness, salinity, overflow, etc.

## III. Survey for irrigation projects

Determination of suitability of soils for establishment of irrigation projects on an area (1, 2) Scale 1:10,000 or 1" = 833' (1 sq. in. = 16 acres). The following factors are studied :

### 1. Soil

- a. depth
- b. permeability
- c. presence of gravel layers in profile
- d. infiltration capacity (6)

2. Relief - its variability and how it affects feasibility of irrigation.



## 3. Erosion

## 4. Land use

## 5. Special factors such as stoniness, presence of boulders and gullies, salinity, etc.

## IV. Crop adaptability survey

Determination of suitability of a soil for a particular crop.  
Scale 1:10,000. Factors to be considered :

## 1. Soil

- a. texture
- b. drainage
- c. acidity
- d. inherent fertility

## 2. Topography

Whether favourable for mechanization

## 3. Climate

- a. temperature
- b. rainfall - annual distribution, seasonal variation
- c. winds
- d. other factors

## 4. Erosion

## V. Economic land classification

A classification of the land on the basis of the intensity of use to which it is adapted as basis for drafting a sound program of land use (4). Scale 1:25,000 or 1" = 2083' (1 sq. in. = 100 acres). Factors considered :

## 1. Soil

- a. texture
- b. drainage
- c. fertility
- d. reaction
- e. depth

2. Erosion
3. Climate
4. Land use
5. Location
6. Various economic factors

#### VI. Geographic land classification

Detailed studies of land utilization in relation to the physical conditions of the land. Basic information for planning for future land use (3). Scale 1:10,000.

Observations are made on :

##### 1. Land conditions

###### a. soil

- (1) effective depth
- (2) texture of surface soil
- (3) underlying material
- (4) permeability of subsoil
- (5) organic content
- (6) chemical reaction
- (7) natural soil drainage
- (8) inherent fertility

- b. slope - its influence upon drainage, erosion, and cultivation.
- c. drainage - significance regarding tillage.
- d. erosion
- e. stoniness and rock exposure

##### 2. Land utilization

#### VII. Classification for assessment purposes

Classification of rural lands for evaluation of property on basis of its actual value (7). Scale 1:10,000. Factors considered :

1. Potential productive capacity of the land.
  - a. chemical and physical properties of soil
  - b. erosion
  - c. topography

2. Accessibility to parts and markets.
3. Existing irrigation facilities.
4. Market price.
5. Production quotas.
6. Other economic factors.

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2. Bonnet, J.A. and Lugo López, M.A., Soil studies in the Coamo valley, Unpublished final report, Agr. Exp. Sta., U.P.R., 1949.
3. Dyer, Donald D. and Jones, Clarence F., "Land classification programme in Puerto Rico," Paper submitted to Caribbean Soils Conference in Puerto Rico.
4. Hernández-Ramírez, M., "Socio-economic study of Southwestern Puerto Rico," Jour. of Agr., U.P.R., 31, 1-165, 1947.
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6. Nelson, L.B. & Muckenhirn, R.J., "Field percolation rates of four Wisconsin soils having different drainage characteristics," Jour. Am. Soc. Agron., 33(11), 1028-1036, 1941.
7. Rodríguez, David A., "Assessment system in Puerto Rico with special reference to rural lands," Paper submitted to Caribbean Soils Conference in Puerto Rico.
8. Roberts, R.C., Soil survey of Puerto Rico, U.S.D.A. in cooperation with Agricultural Experiment Station, U.P.R., Series 1936, No. 9, 1942.
9. Soil Conservation Service, U.S.D.A., Guide for soil conservation surveys, 1948.

## A N N E X 4

### LABORATORY METHODS FOR SOIL AND PLANT ANALYSIS USED IN THE AGRICULTURAL EXPERIMENT STATION UNIVERSITY OF PUERTO RICO

By

J.A. Bonnet, Head; M.A. Lugo López, Asst. Soil Technologist;  
and A.R. Riera, Asst. Chemist, Soils Department

#### I. Sampling

##### 1. General soil sampling technique

Cline, M.G., "Methods of preparing and collecting soil samples,"  
Soil Sc., 59, 3-5, 1945.

##### 2. Soil core sampling technique

Coile, T.S., "Soil Samplers," Soil Sc., 42, 139-142, 1936.

Kelley, O.J., Hardman, J.A., and Jennings, D.S., "A soil sampling  
machine for obtaining two, three, and four inch diame-  
ter, cores of undisturbed soil to a depth of six feet,"  
Soil Sc. Soc. Amer. Proc., 1947, 12, 85-87, 1948.

##### 3. Plant tissue sampling

For grasses - one-third at the end of the fourth leaf from ran-  
domized plants.

#### II. Preparation of the sample

##### 1. Soils

###### a. For general work

Samples are air dried and passed through a 2 mm. sieve.

###### b. For special work

Methods of Analysis of the Association of Official Agricultural  
Chemists, 6th Ed.; 1945.

Soil Sc., 59, Jan., 1945.

Soil Sc., 68, July, 1949.

## 2. Plant tissue

Samples are dried in the oven at 70°C, ground in micro Wiley mill, and sifted through a 40 mesh sieve.

## III. Physical measurements

### 1. Texture

#### a. Hydrometer

Fouyoucos, G.J., "The hydrometer as a new method for the mechanical analysis of soils," Soil Sc., 23, 343-353, 1927.

#### b. Decantation - Osborne's method

Methods of the mechanical analysis of soils and of the determination of the amount of moisture in soils in the field, USDA, Div. of Soils, Bul. 4, 1896.

#### c. Pipette

Jennings, D.S., Thomas, M.D., and Gardner, M., "A new method of mechanical analysis of soils," Soil Sc., 14, 485-499, 1922.

### 2. Structure

#### a. Structure measurements based on soil porosity.

$$\frac{\text{True density} - \text{apparent density}}{\text{True density}} \times 100 = \frac{\text{Total soil volume occupied}}{\text{by voids}}$$

Russell, M.B., "Methods of measuring soil structure and aeration," Soil Sc., 68, 25-36, 1949.

#### b. Structure measurements based on soil aggregate.

Falling drop technique.

McCalla, T.M., "Water-drop method of determining stability of soil structure," Soil Sc., 58, 116-122, 1944.

### 3. Mineralogical analysis of soils

#### a. Specific gravity separation of soil minerals

Bonnet J.A., "The nature of laterization as revealed by chemical, physical, and mineralogical studies of a lateritic soil profile from Puerto Rico," Soil Sc., 48, 25-40, 1939.

#### b. Petrographic microscope.

Marshall, C.E. and Jeffries, C.D., "Mineralogical studies in soil research ; I," Soil Sc. Soc. Amer. Proc., 1945, 10, 397-405, 1946.

#### c. X-Ray spectrometers

Jeffries, C.D., "The use of x-ray spectrometer in the determination of the essential minerals in soils," Soil Sc. Soc. Amer. Proc., 1947, 12, 145-150, 1948.

### 4. Moisture studies

#### a. Field moisture content

(1) gravimetric determination by drying a sample in an oven, at 110°C.

(2) energy measurements

##### (a) tensiometers

Richards, L.A. "Soil moisture tensiometer materials and construction," Soil Sc., 53, 241-248, 1942.

##### (b) electrical resistance method

Bouycucos, G.J. and Mick, A.H. An electrical resistance method for the continuous measurement of soil moisture under field conditions, Mich. Agr. Exp. Sta., Tech. Bul. 172, 1940.

#### b. Field capacity

Weaver, J.E. and Clements, F.E., Plant Ecology, New York, McGraw Gill Book Company, Inc., 1938.

## c. Moisture equivalent

Briggs, L.J. and McLane, J.W., The moisture equivalent of soils, USDA, Bur. Soils, Bul. 45, 1-23, 1907.

## d. Permanent wilting point

Briggs, L.J. and Shantz, H.L., The wilting co-efficient for different plants and its indirect determination, USDA, Bur. Plant Indus., Bul. 230, 1-83, 1912.

Hendrickson, A.H. and Veihmeyer, F.J., "Permanent wilting percentages of soils obtained from field and laboratory trials," Plant Physiol., 20, 517-539.

Richards, L.A. and Weaver, L.R., "Fifteen atmosphere as related to the permanent wilting percentage," Soil Sc., 56, 331-340, 1943.

## e. Permeability

Files, B.P.I. - S.C.S. Research Laboratory, Agricultural Experiment Station, Río Piedras, Puerto Rico.

## f. Complete pF curve

Bonnet, J.A. and Lugo López, M.A., Final report of soil studies in the projected Coamo irrigation area, Unpublished, Agr. Exp. Sta., Univ. of P.R., 1949.

## IV. Chemical measurements

## 1. Base exchange

## a. The determination of exchangeable bases (Ca, Mn, Mg, Fe, P) and total exchange capacity with normal ammonium acetate.

Peech, Michael, "Determination of exchangeable bases in soils," Industrial and Engineering Chemistry, Analytical Edition, 15(6), 436-441, 1941.

Peech, Michael, "Determination of exchangeable cations and exchange capacity of soils - Rapid micrometric methods utilizing centrifuge and spectrophotometer," Soil Sc., 59, 25-38, 1945.

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Bonnet, J.A. and Riera, A.R. "Tracing the mineral from the soil to the plant to the animal blood. Part I. Effect of lime on the mineral composition of the soil, of the grass, and on the crop yield," Jour. of Agr., Univ. of P.R., 30, 138-158, 1946.

b. Determination of exchangeable potassium and sodium.

Attoe, O.J. and Truog, E., "Rapid photometric determination of exchangeable potassium and sodium," Soil Sc. Soc. Amer. Proc., 1946, 11, 221-226, 1947.

2. Organic matter

a. Rapid test

Genco Wilde organic matter color scale. Cat. No. 28303, Central Scientific Co., Chicago.

b. Schollenberger method

Schollenberger, C.J., "Determination of Soil organic matter," Soil Sc., 59, 53-56, 1945.

3. Total nitrogen - Kjeldahl method.

Methods of Analysis of the Association of Official Agricultural Chemists, 6th Ed., 1945.

4. pH

a. Glass electrode - (Macbeth, Cameron, Titrometer, Beckman) soil water extract ratio of 1:2.5.

b. Quinhydrone electrode.

5. Conductivity - for total soluble salts in soils 1:2 soil water suspension. Solu Bridge.

Bonnet, J.A., "Laboratory and field studies in an alkaline earth solonchak area of Puerto Rico to be irrigated," Proc. Soil Sc. Soc. Amer., 1945, 11, 480-483, 1946.



## 6. Lime requirement

Riera, Alfonso, "Lime requirements of soils," Jour. of Agr., Univ. of P.R., 30, 184-185, 1946.

7. Analysis of water extract (Total solids,  $\text{HCO}_3$ ,  $\text{CO}_3$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{SO}_3$ ,  $\text{Cl}$ ,  $\text{CaO}$ ,  $\text{MgO}$ )

Methods of Analysis of the Association of Official Agricultural Chemists, 6th Ed., 1945.

8. Fusion analysis (Total  $\text{SiO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{TlO}_2$ ,  $\text{MnO}$ ,  $\text{P}_2\text{O}_5$ ,  $\text{CO}_2$ ,  $\text{SO}_3$ ).

Methods of Analysis of the Association of Official Agricultural Chemists, 6th Ed., 1945.

## 9. Copper and cobalt determinations

Holmes, R.S., "Determination of total copper, zinc, cobalt and lead in soils and soil solutions," Soil Sc., 59, 77-84, 1945.

## 10. Iodine and fluorine determinations

Methods of Analysis of the Association of Official Agricultural Chemists, 6th Ed., 1945.

## 11. Available nutrients

Bonnet, J.A. and Villamil, F.A., "Research on shortening time without affecting the accuracy of Dyer's modified method for determination in soils, of phosphoric acid, lime, and potash soluble in citric acid solution," Jour. Dept. of Agr. of P.R., 17, 287-300, 1933.

## 12. Boron determination in soils

Truog, E., "Determination of total and available boron in soils," Soil Sc., 59, 85-90, 1945.

Colwell, W.E., "A biological method for determining the relative boron contents of soils," Soil Sc., 56, 71-74, 1943.

### 13. Plant analyses

R.Q. Parks and G.H. Ellis, "Quantitative chemical microdetermination of twelve elements in plant tissue - (Ca, Fe, P, Mg, Mn, Cu, Co, Zn)," Industrial and Engineering Chemistry, Analytical Edition, 527-533, 1943.

Bonnet, J.A. and Riera, A.R., "Tracing the mineral from the soil to the plant to the animal blood. Part I. Effect of lime on the mineral composition of the soil, of the grass, and of the crop yield," Jour. of Agr., Univ. of P.R., 30, 138-158, 1946.

### 14. Foliar diagnosis

Wander, I.W., "Total potassium in plant material," Industrial and Engineering Chemistry, Analytical Edition, 14, 471, 1942.

Wolf, Benjamin, "Total nitrogen and phosphorus in plant material," Industrial and Engineering Chemistry, Analytical Edition, 16(2), 121.

## V. Microbiological determinations

### 1. Nitrification rate

Bonnet, J.A., "Nitrification studies with soil types of northern Puerto Rico," Jour. Dept. of Agr. of P.R., 19, 73-103, 1935.

### 2. Microbial population in soils

Bonnet, J.A., "Nitrogen transformation in the decomposition of sugar cane trash, with special bearing upon Puerto Rico soil problems," Jour. Dept. of Agr. of P.R., 15, 113-146, 1931.

SURINAM

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Problems

Recommendations

Survey of Existing Conditions

I. Soil Forming Factors Data

- |  |   |  |
|--|---|--|
| (1) Some geological information available (Ijzerman, <u>Outline of Geology and Petrography of Surinam, 1931</u> ).   | Need for more geological information especially for the coastal belt. | Seek cooperation of the Geological and Mining Service.                               |
| (2) Aerial photographs of the northern half of Surinam available on a scale of 1:40,000 and partly, too, on a scale of 1:20,000, as well as photomosaics on a scale of 1:100,000 and 1:40,000. | Need for base maps on a scale of 1:10,000.                            | Seek cooperation of the Crown Land Office and the Central Bureau for Aerial Surveys. |
| (3) Rainfall data available for many stations, mostly coastal.   | Need for more detailed information on rainfall.                       |  |

Temperature, relative humidity and wind data available for two stations (Paramaribo and Nickerie) (Braak, Mededelingen en Verhandelingen van het Koninklijk, Nederlands Meteorologisch Instituut, No. 36; Overzichten der Meteorologische waarnemingen in

Survey of Existing Conditions

Problems

Recommendations

I. (3) (Contd.)

Nederlands W-Indie, Kon.  
Ned. Meteor. Inst.)

Evaporation data lacking.

Need for information on evapora-  
tion.

Seek cooperation of British and  
French Guiana.

- (4) Fair amount of informa-  
tion on vegetation  
(Pulle, Flora of Surinam,  
Vol. I, II, III, IV;  
Stahel, Nuttige planten  
van Suriname, Bull.  
Agric. Exp. Station, No.  
59, 1944).

Information on plant so-  
ciology lacking.

Need for plant sociological  
studies.

II. Standardization of Soil  
Survey Methods

- (1) Mapping is being done on  
kodatrace covering an  
aerial photograph (con-  
tact print or enlarge-  
ment).

Soil samples are taken  
by means of the Dutch  
auger.

Seek advice and cooperation of  
pedologists in other countries.

- (2) The routine methods for  
analysis of soil samples  
include : pH-water,  
pH-KCl, organic matter,

Need for increasing the capacity  
of the laboratory.

Need for standardized laboratory

Introduction of rapid chemical  
tests for analysis of tropical  
soils.

<u>Survey of Existing Conditions</u>	<u>Problems</u>	<u>Recommendations</u>
<p>II. (2) (Contd.)</p> <p>calcium carbonate, available phosphate, available potash, total exchangeable bases, hydrolytic acidity and mechanical analysis (fractions : 2-8-16-53-74-105-149-210-297-420-590-840-1000-1410-2000 microns).</p>	<p>methods on physical soil properties.</p>	<p>Seek advice and cooperation of soil chemists in other countries.</p>
<p>III. <u>System of Soil Classification and Mapping</u></p> <p>No definite decision has yet been made concerning nomenclature.</p>	<p>Need for a system of classification especially adapted to soils derived from pleistocenic and holocenic formations.</p>	<p>Seek advice and cooperation of pedologists in other countries.</p>
<p>IV. <u>Detailed Regional Programme of Soil Survey</u></p> <p>A detailed survey of an area west of Paramaribo (7,500 acres), on a scale of 1:10,000, is in progress.</p> <p>Some reconnaissances, mostly in the north-west part of Surinam, have been made.</p>	<p>Urgent need for soil maps on a large scale of areas under cultivation to improve land use, and for soil maps on a small scale of undeveloped areas for new settlements.</p>	<p>Seek financial aid under the Netherlands Development and Prosperity Fund for Surinam, to speed up the work as much as possible.</p>
<p>V. <u>Survey of Soil Erosion, Conservation, Renovation</u></p> <p>Nothing yet attempted.</p>	<p>Need for a programme to check</p>	<p>As under IV.</p>

Survey of Existing Conditions

Problems

Recommendations

VI. Application of Soil Survey  
to Land Utilization

Annexed to the detailed soil survey west of Paramaribo, a land use map, some farm management research, etc., are being made of this area, to obtain sufficient data for land improvement.

Need for a land capability survey.

As under IV.

TOBAGO

<u>Survey of Existing Conditions</u>	<u>Problems</u>	<u>Recommendations</u>
<u>I. Soil Forming Factors Data</u>		
1. Some geological data available (Cunningham-Craig; Trechmann, etc.).	Need for further petrological information and for geological maps.	Seek cooperation of geologists.
2. Road map available but only sparse topographical data.	Need for further topographical data.	As above.
3. Some rainfall data available.	Need for more meteorological data.	Seek help from Hydrological Dept. of Trinidad.
4. Excellent descriptions (J.S. Beard) of vegetation available.	Need for information on forest undergrowths and cultivation weeds as "markers".	Seek further cooperation of Forest Department and botanists.
<u>II. Standardisation of Soil Survey Methods</u>		
Methods used in Trinidad soil survey (Chenery) have been used in Tobago.		Seek help from Dept. of Agriculture, Trinidad, for services of soil surveyor, and from British Caribbean Soil Survey.
<u>III. Systems of Soil Classification and Mapping</u>		
Classification method of U.S.D.A. ( <u>Soils and Men</u> , 1938) applied to soils of Tobago (Chenery).	Intensification of soil survey needed.	As II.

Survey of Existing Conditions

Problems

Recommendations

IV. Detailed Regional Programme  
of Soil Survey

Report and soil map available  
(Chenery), but not yet pub-  
lished.

Publication of soil map needed. As II.

Seek aid from Government  
Cartographers for publication  
of soil map.

V. Survey of Soil Erosion, Con-  
servation, Renovation

Articles on soil erosion in  
Tobago published (Hardy).

A detailed survey of erosion  
awaits attention, especially  
of recent flood damage.

As II.

Seek aid from U.S. authorities.

VI. Application of Soil Survey  
to Land Utilization

No attempt yet made.

Elaboration of agricultural  
systems suited to the pre-  
vailing economic and ecologic  
circumstances urgently needed.

Formation of a committee or  
initiation of discussions  
among interested parties.

Seek aid from U.S. authorities.

TOBAGO



TRINIDAD

Survey of Existing Conditions

Problems

Recommendations

I. Soil Forming Factors Data

- |  |   |   |
|--|---|---|
| 1. Much detailed geological information available from oil geologists. Several books and articles on local geology published and some sketch maps. A comprehensive treatise, with maps, now under consideration by Trinidad Leaseholds, Ltd. Lithological maps already prepared. | Need of more geological information for Northern Range area.                                      | Seek further cooperation of oil geologists and of the Government Geologist.                     |
| 2. Fair topographical maps available (road maps, etc.). Much information in archives of oil companies.   | Need for more accurate topographical information of some type-areas.                              | As above.   |
| 3. Climatological data available for many stations.  | Need for extension of rain gauge stations, and for <u>recording</u> rain gauge.                   | Seek help from new Hydrological Dept. of Trinidad.  |
| 4. Excellent memoir (J.S.Beard, 1946) on vegetation of Trinidad, with good map (1:50,000 and 1:150,000).   | Need for more information on forest undergrowths and of cultivation weeds as soil-type "markers". | Seek further cooperation from Forest Dept., local botanists and Botanical Dept. of the I.C.T.A. |

II. Standardisation of Soil Survey Methods

Soil survey methods have been standardised; auger and pit method (Hardy, Chenery,

Seek further help from Department of Agriculture for services of soil survey officer. Possible

Survey of Existing Conditions

Problems

Recommendations

II. (Contd.)

Charter, Witt).

help from British Caribbean Soil Survey.

III. Systems of Soil Classification and Mapping

1. System devised by Charter applied to sugar cane lands.

Problems of the Northern Range soils still await investigation.

As II.

2. System devised by Chenery applied to middle part of Trinidad.

3. Both systems stress drainage as the main soil forming agency, depending on topography and permeability of parent materials.

IV. Detailed Regional Programme of Soil Survey

1. Chenery's latest report and soil map are not yet published, though available.

Completion of the soil survey of the whole of Trinidad needed. Publication of soil maps urgent.

As II.

2. Extension of the area surveyed by Chenery now being undertaken. (G. Witt).

Seek aid from Government cartographers for publication of soil maps.

TRINIDAD

<u>Survey of Existing Conditions</u>	<u>Problems</u>	<u>Recommendations</u>
<b>V. <u>Survey of Soil Erosion, Conservation, Renovation</u></b>		
1. No general policy for soil conservation yet in operation.	General extension of soil erosion survey needed.	As II.
2. A Land Allocation Policy was formulated in 1944 by Brooks.	Propaganda needed to make planters and peasants "erosion-conscious".	Seek aid from U.S. authorities.
3. Articles on soil erosion in Trinidad have been published in <u>Tropical Agriculture</u> by Cater and by Hardy.	Need for revision of legislation regarding land tenure.	
4. A Soil Erosion Officer, trained in U.S.A., is a member of Department of Agriculture Staff.		
<b>VI. <u>Application of Soil Survey to Land Utilization</u></b>		
See V. A map by Chenery of Land Utilization has been published ( <u>Tropical Agriculture</u> , 1940).	Elaboration of agricultural systems suited to the prevailing economic and ecologic circumstances urgently needed.	Formation of a Committee; or initiation of discussions among interested parties.  Seek aid from U.S. authorities.

ANNEX

SOIL EROSION IN TRINIDAD

By

G.C. Witt, Soil Survey Officer, Department of Agriculture

The problem of soil erosion in the Colony was studied by Professor Hardy and his findings were published in Tropical Agriculture in 1942 (XIX, No. 2, pp. 29-35). In this article the types, the causes and, in some instances, the status of erosion are discussed in relation to the main topographical divisions, and the information set out forms an extremely useful basis for further study with the object of evolving sound land use principles, as well as adequate practical measures for combating erosion. Stress is also laid on the absence and need of a general policy by which the problems may be widely appreciated, and concerted action taken to combat them.

During the same year of publication of this article the Agricultural Policy Committee was appointed, whose terms of reference included, inter alia, a definition of the objectives of a policy for agricultural development, the formulation of a long term policy for such agricultural development, the laying down of broad lines of experiment and research programmes, etc. In the report of this Committee, published in 1943, one of the main objectives stressed was the conservation of the natural resources of the Colony, and specific policy recommendations were made in respect of the conservation of soil. Some of these recommendations are :-

- (a) Survey of the existing condition of the soil, with a view to ascertaining the direct and indirect causes of erosion and investigating and applying effective remedies.
- (b) Regulation of land use.
- (c) Investigation and demonstration of farming systems which aid soil conservation, e.g., mixed farming on a stock-keeping basis.
- (d) Development of soil consciousness in the community by such means as education, propaganda and demonstration.
- (e) Re-organisation of the Department of Agriculture to render its services more effective in the improvement of agriculture generally.
- (f) State aid for such soil conservation projects as purchase and use of artificial manures, mixed farming, anti-erosion and drainage measures, afforestation of approved areas, etc.

In 1947 an officer of the Department of Agriculture was assigned to follow the field training course offered by the U.S.D.A. Soil Conservation Service, with the object of obtaining first hand information on the methods and techniques employed by that agency in the Federal programme of Soil Conservation in the United States. This officer assumed duties in connection with soil conservation work in Trinidad and Tobago in July, 1949, and the initial step was taken in the organization of a course of training for the field staff of the Extension Services in the principles and field practice of soil conservation with special reference to local conditions. This training programme is still in progress and, when it is completed, the next logical step will be embarked upon, that is, propaganda aimed at focusing public attention on the direct and attendant evils of soil erosion as well as the need for, and benefits to be derived from, concerted effort in the application of remedial measures.

Concurrently with propaganda and education will go the establishment of suitable demonstrations in locations representative of the main problem areas. Up to the present no public funds have been provided for the initiation of this phase of the work. However, the lead in the establishment of soil and water conservation practices on a field basis was taken by one of the large sugar companies about 1946 and the work is being extended from year to year.

#### Land Use in the Colony

It is accepted at the present time that certain aspects of past and present land use may be held responsible for the rapid soil degradation which has occurred over sizeable acreages in the Colony. A radical change in policy with regard to the future use of these areas is a prime necessity, and is best based on conservation surveys to determine the nature, degree and distribution of those physical land characteristics which limit the safe use of the land for agricultural purposes. Such surveys will not only serve to indicate the areas or sections which should under no circumstances be subjected to a regime of agricultural production, but also to prescribe the limits in usage as well as the treatment necessary to maintain the highest possible standard of production on the remainder consistent with its capability for agricultural use.

The Soil Survey of the Colony is far from being complete, but, wherever erosion problem areas occur within areas already surveyed, the delineation of other important physical factors such as slope conditions, and nature and degree of past erosion, are useful in securing information relevant to land use determination in the Colony. There exists, however, a serious handicap to the accurate mapping of a conservation survey in the absence of suitable base maps showing details of relief and other features. Aerial photographs are available, but their scale is far too small to allow of their use in the field. Should it become necessary or practicable to

to provide state aid for soil conservation in the future, the information provided by the conservation surveys would be indispensable in fixing the land use requirements for qualification.

### Erosion Control Work in Trinidad and Tobago

The Ste. Madeleine Sugar Company is credited with the initiation of contouring as a means of overcoming the drought effects which young sugar cane suffers in varying degrees during the dry season. This practice has yielded very encouraging results in the direction of increased tonnages of both plant and ratoon canes, and its application is being extended every year.

### Soil Conservation in relation to the major crop industries

A brief review of the main agricultural crops will serve to provide a better appreciation of their relative contribution to the present status of erosion in the Colony. Cacao occupies a greater acreage in Trinidad than all the other agricultural crops combined (212,000 acres by planimetric estimates in 1938). Due to abandonment as well as conversion to War Gardens, this area is now reduced to an estimated 160,000 acres. The conditions of growth of this crop more nearly approach those of natural forest than any other agricultural crop, and, in consequence, the rate of erosion on land occupied by it would be expected to approximate the normal or geological rate. This has been a very fortunate circumstance for Trinidad, and the same holds true for Tobago, where the majority of the lands under cacao are steeply sloping.

Sugar cane also occupies a large land area (106,000 acres), the greater proportion of which, however, is either flat land subject in parts to mild flooding, or mildly sloping and, therefore, not prone to serious erosion. The remainder, comprising rolling land, constitutes a problem in view of the increasing steps being taken in the mechanization of tillage operations, for it is a well-recognized fact that indiscriminate ploughing by systematically moving topsoil in body down hill can accomplish, and at a considerably accelerated rate, the same end result of soil depletion on the crests and upper slopes, as water erosion alone.

The acreage under citrus has expanded rapidly from the figure of 5,000 acres in 1938, mainly as a result of the adoption of this crop as a replacement for cacao on soil unsuitable to the latter. Apart from crown weeding of individual trees, it is a normal practice to maintain a permanent cover of grass, and this in itself provides adequately against the possibility of severe soil loss on sloping lands. The same applies to other permanent crops.

The food crop industry is the greatest single agency of land

abuse in the Colony. Apart entirely from the harmful practices of burning of lands and shifting cultivation, the layout and cultivation of "gardens" leave much to be desired by way of modification in order to satisfy the all important needs of adequate erosion control and sustained productivity. The problem is rendered all the more difficult by the scattered nature of the gardens and the relatively large areas of derelict or semi-derelict land which they straddle. In some of these areas the problem to be tackled involves either permanent retirement of the land or the institution of measures of soil renovation. Most of the land in these areas is under private ownership and occurs on moderate to steep topography.

VIRGIN ISLANDS OF THE UNITED STATES

Survey of Existing Conditions

Problem

Recommendations

I. Soil Forming Factors Data

Limited records available on rainfall, temperature, wind velocity and evaporation rates. Topography is indicated on 1:10,000 Coast and Geodetic Survey map.

Soil Reconnaissance by James Thorpe, 1932, shows soil types and land capability. Basic soil origin volcanic and calcareous.

Aerial survey photographs by U.S. Army show vegetation and land use.

Need for organized, authentic and elaborated data on soil forming factors with a determination of their influence on soil formation and maintenance.

Expansion of personnel and provision of facilities at the local Agricultural Stations for the purpose of conducting research and experiments to furnish the information needed.

II. Field and Laboratory Methods of Soil Survey

Physical and chemical measurements of soils are not made at present. However, the U.S. Soil Conservation Service has started a field survey of Virgin Islands soils in order to bring up to date the work done by Thorpe in 1932.

Need for increasing the number of agents working on this survey so that it may be completed as rapidly as possible. This survey is essential for intelligent farm planning and land use.

Indicate this need to the authorities of the U.S. Soil Conservation Service and urge early attention to the matter.



<u>Survey of Existing Conditions</u>	<u>Problems</u>	<u>Recommendations</u>
<p>III. <u>System of Soil Classification and Mapping</u></p>	<p>As indicated above, the need is for speedy completion of all soil mapping and classification routine.</p>	<p>See above.</p>
<p>The Soil Conservation Work is conducted under the supervision of the U.S. Soil Conservation Service in Puerto Rico. The methods used for textural topographic and geologic classification of soils are those standard for that Service.</p>		
<p>IV. <u>Soil Erosion, Conservation and Renovation</u></p>		
<p>Soil erosion heavy, arising particularly from indiscriminate clearing of mountain areas which should normally remain in forest or grass.</p>	<p>Lack of reliable information. Need for technical and laboratory facilities to procure the necessary information.</p>	<p>Petition U.S. Congress to create research department in the local Agricultural Stations.</p>
<p>U.S. Soil Conservation Service provides limited technical assistance for establishing soil and water conservation plans on farms.</p>	<p>Lack of knowledge and appreciation of the importance of soil conservation.</p>	<p>Increase Extension Services to educate the people in the importance of soil conservation.</p>
<p>A 10-year Master Plan has been drafted for the Virgin Islands indicating the soil and water conservation needs. It includes land capability figures,</p>	<p>Need for greater technical and financial assistance for carrying this programme through to a successful completion.</p>	<p>Enact legislation to provide for forest protection and proper land use.</p>
		<p>Seek administrative cooperation in urging passage of the bill before Congress to appropriate the funds estimated by the U.S. Soil Conservation Service as needed for the establishment of the recommended soil and water conservation practices for the</p>

Survey of Existing Conditions

Problems

Recommendations

IV. (Contd.)

problem areas, terracing, contour furrowing, construction of farm ponds, legume planting, and barrier establishment by rock and vegetation.

Virgin Islands.

V. Practical Application of Soil Surveys to Land Utilization

Soil Conservation work in the Islands is carried on by local Soil Conservation District Boards. They determine ways and means by which the plans established by the U.S. Soil Conservation Service may be implemented. Their agents arrange for loans, financial assistance, equipment and all other facilities which will permit practical execution of soil and water conservation plans.

The Production Marketing Association makes cash benefit payments to farmers who adopt these practices. These incentive payments encourage conservation work generally.

Boards work without compensation so that the time and effort required for promotional work are often lost.

Lack of adequate finance for purchasing equipment and conducting the programme in general.

The main office is located in St. Croix. Agent seldom visits St. Thomas and St. John as expenses for travel are not reimbursed.

Arrange for compensation of officers to the extent of expenses incurred during performance of Services.

Provide fund commensurate to the present needs of the programme.

Bring this situation to the attention of Production Marketing Association authorities with request for amelioration.

Survey of Existing Conditions

Problems

Recommendations

V. (Contd.)

The Agricultural Extension Service cooperates with all agencies to educate the farmers and assist them with soil and water conservation work.

The Farm Home Administration allows long term operating loans to farmers for carrying out conservation plans.

The following is the extent of practical applications of soil survey in the Virgin Islands :-

Insufficient number of agents on Station staff.

Urge passage of bill now before Congress to transfer Station from Dept. of Interior to U.S.D.A. This will automatically provide for increase in personnel and other advantages.

PRACTICES	UNIT	PLANNED	APPLIED TO DATE
Contour farming	acres	4,993	1,395
Cover cropping	"	3,730	59
Stubble mulching	"	5,072	1,189
Pasture improvement	"	18,866	7,515
Pasture seeding	"	13,801	4,207
Woodland management	"	4,726	1,007
Tree planting	"	662	3
Farm ponds	number	76	33
Terraces	miles	61	18
Field diversions	"	3	0
Irrigation land preparation	acres	34	19
Improved water application	"	43	13
Crop rotation	"	4,366	758
Water disposals	"	3	3
Kudzu	"	16	5

## A P P E N D I X B

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### S E M I N A R D I S C U S S I O N S

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#### A. A LAND IMPROVEMENT PROGRAMME FOR THE CARIBBEAN

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##### 1. Soil Classification and Research in a Caribbean Land Improvement Programme

By Roy W. Simonson

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In preparing for the seminar discussion, I first asked the question: What are the needs for soil classification and research in a land improvement programme in the Caribbean region? It is much easier to ask that question than to answer it, especially for me. My own experience has been largely in the United States, though I have had the opportunity to see soils and land utilization in Hawaii and other Pacific islands. A number of the soils and much of the agriculturè resemble those of Puerto Rico. From my own experience in the Pacific, and from our experience in the soil survey of Puerto Rico, I have come to believe that the principles gained through the soil classification and research programmes in the United States may be carried successfully to other regions, including Caribbean lands. The emphasis within those programmes, perhaps the approaches followed, and certainly some of the techniques employed will have to be different. Even so, it may be helpful for us to discuss objectives and needs of soil classification and research, the scope of soil classification, programmes of soil mapping and surveys, and research on the properties and behaviour of soils. Before I make my try, however, I do want to ask that each of you temper what I do say with the knowledge you have gained from your own much wider experience in the Caribbean region.

##### Objectives and Needs of Soil Classification and Research

The ultimate objectives of soil science in agriculture and forestry are to predict the yields of crops, grasses, and trees under defined systems of management and the long-time effects of use and management on the soil. Thus, our objectives are twofold. Furthermore, this statement is far more simple than the objective. A great deal of effort is necessary, both in soil science and in related fields, before the objectives can be achieved, even in areas where investigations have been under way for a long time. The amount of work needed is even greater where the research facilities in the past have been limited and are still restricted. To achieve the general objective, research must be carried on both in fundamental and applied phases of soil science. Furthermore, there must be a constant interchange of experience and information on the part of soil sci-

entists with scientists in other fields, such as agronomy, horticulture, forestry and engineering.

Information is needed at many different levels of generalization. The degree of detail necessary in outlining undeveloped areas for prospective settlement or for zoning differs a great deal from that needed in the development of drainage or irrigation projects. The degree of detail necessary in the latter type of project is much the same as that required for the giving of specific advice on use and management of soils within established farms. The prime functions of classification and research are to provide means of organizing, evaluating and extending available data at whatever level necessary. These levels range from the most general to the most specific; they cover the whole range of public and private planning.

Briefly, the necessary information about soils will be the kinds, characteristics, extent, distribution and behaviour in agriculture, forestry and engineering. Part of this information can be obtained from field surveys, and part of it must be collected from the experience of farmers, foresters, and engineers; from government programmes of various kinds; and from planned research. Recognizing all this, however, we still face the question of where to start a programme or where to expand a programme already under way.

#### Scope of Soil Classification

The soil is a natural body occurring on the land surface of the earth, having a unique morphology, and lying within the rooting zone of plants. This definition will be used throughout the paper, although I realize that the word "soil" has a number of meanings. In order to understand the soil and its behaviour as fully as possible, we must determine its characteristics or properties and correlate the behaviour of the soil under various sets of circumstances with those properties. Furthermore, these properties or characteristics must be considered collectively, both in classifying soils and in interpreting their behaviour.

It is essential that a genetic thread or central concept of genesis run through an entire scheme of classification in order that it show the relationships of soils in one place to those of another place. A uniform classification which recognizes significant differences and similarities is essential in order to permit the transfer of knowledge gained in one geographic area to the soils in another geographic area. Moreover, such a system of classification can only be constructed around the central concept of the profile and its development, within our present state of knowledge. This scheme, once perfected, promises to permit the transfer of information at various levels of generalization.

The specific units recognized in soil classification in the United States are soil types and phases. The soil type is defined primarily in terms of the profile, whereas phases are more commonly distinctions within types on the basis of external features, such as slope, degree of erosion or stoniness. The characteristics considered in the classification of soils into types and phases includes both observable and inferred properties. The principal observable features are the number, thickness and arrangements of horizons in a profile; the colour, structure, texture, consistence and reaction of the individual horizons; the contents of carbonates and soluble salts in the soil; and the slope, stoniness, parent material and underlying rock. The principal inferred properties considered are natural drainage, contents of organic matter, fertility levels and degree of erosion.

Soil types and phases have limited ranges in their various characteristics, and they occupy small segments of a land surface. In a sense, they are geographic bodies with well defined surfaces, less obvious perimeters, and rather indefinite lower boundaries. In other words, any given area of a soil type or phase is a three-dimensional entity. If we think of the world as a globe comparable to an orange, each area of a soil type or phase is like a small piece of the rind. Soil types and phases are intended to be specific enough to provide a framework for the organisation, evaluation, and extension of information on the use and management of soils within fields or comparable units in farms or forests. The objective is to define mapping units that are sufficiently homogeneous for the making of differential predictions based on experience and research.

After the soil types and phases have been defined, they can be grouped in a number of ways. In the natural scheme of classification, they are grouped into series, families, great soil groups, suborders and orders, none of which is shown on detailed soil maps. Each of these groups necessarily encompasses an increasingly greater number and wider range of genetically related soils. These groups are intended primarily to show relationships in morphology and genesis of soils, and thus aid in extending the sum total of our knowledge in soil science. None of these groups is suitable for such specific uses as the application of information on soil use and management to individual fields.

Technical groupings are a widely used device for integrating data from soil surveys with other information to deal with problems in the use of soils for agriculture, forestry or engineering. In this discussion, a technical grouping is defined as a classification of soils, usually into a small number of classes, for a specific practical objective. Soils have been grouped into five classes according to use-suitability in soil surveys made in the Tennessee Valley. This is one example of a technical grouping. Another example is the widely used grouping of soil types and phases according to management requirements. This grouping is made generally in

current soil surveys in the United States. Because there is a larger number of classes in the management grouping than in the use-suitability grouping, each management class includes fewer soils, and these are more nearly alike than they are in each of the use-suitability classes. Many other technical groupings have been prepared, and still others will be prepared in the future.

Progress in the development of soil classification rests, in part, upon the morphological studies made in soil surveys, in part upon the testing of concepts by their use in soil mapping, and in part upon investigations of soil properties in the laboratory. All of these elements of a research programme to characterize soils more completely are interdependent, and also rely upon other segments of research programmes. In other words, there are reciprocal influences among all the segments of soil science. To cite but a single example, improved knowledge of soil characteristics calls attention to deficiencies in our scheme of classification. Similarly, improvements in our classification will at times call attention to gaps in our knowledge of soil behaviour. Thus, progress in soil classification depends not only upon the achievement in that one segment of soil science, but also upon advances in other segments of soil science and in science generally.

#### Programme of Soil Surveys and Mapping

The chief purpose of a soil mapping programme is to determine the nature, distribution and extent of different soils. It is also important in testing the classifications already developed, and in further developing the schemes and approaches. The maps must show geographical areas which are homogeneous enough to permit the making of predictions about soil behaviour for the purpose at hand. Small areas must be outlined where a high degree of homogeneity is necessary, as, for example, when farm advisers make specific recommendations for fertiliser use and crop rotations for specific fields. Broad areas with much lower degrees of uniformity are suitable for blocking out lands that might be considered suitable for settlement in undeveloped regions. Consequently, information about the nature, distribution and extent of soils is needed at a number of levels of generalisation. The job in a programme of soil mapping is to meet the various needs as quickly and completely as is feasible. Five steps are, therefore, suggested in this section for a programme of soil mapping in undeveloped areas where little is now known about the soils. I might add that I believe one or more of the steps outlined will be applicable to most of the Caribbean lands.

1. First of all, a soil association map can be compiled from existing sources of information, which might include climatic data, topographic and geologic maps and reports, vegetation maps and reports, aerial



photographs, notes by scientific travellers, and observations from reconnaissance trips. This map would be a first approximation to show soil regions, probably on a small scale. The number of soil associations outlined on the map and the degree of homogeneity of each will be governed largely by the amount of information at hand. In some cases, the scale of the map upon which association areas are outlined becomes the limiting factor in the detail that can be shown.

The several possible sources of information are not all of equal value. Information on climate, topography, geology and vegetation - especially in the form of reliable maps - will be very helpful in the plotting of boundaries of soil associations. Aerial photographs will also be extremely useful. Notes made by scientific travellers, other than soil scientists, will have limited usefulness, but can be used to some degree in the absence of better information. By and large, reconnaissance trips by competent soil scientists will be especially helpful in obtaining reliable information. Such reconnaissance trips should be made wherever they are possible, either during original compilation of the map, or to check it in the early stages of preparation.

Soil associations are areas or bodies of land with a characteristic and recurring pattern of soils. Thus, each association is uniform with respect to soil pattern rather than with respect to soil itself. For the most part, soils occur as small intermingled areas of soil types and phases, usually unlike one another to some degree. In many ways, soil associations are like plant associations. Under natural conditions, certain plants grow together in an area. In the same way, certain soils characteristically occur together, and the area in which they do occur in a characteristic pattern is a soil association. Both soil and plant associations are thus geographic units useful in providing a picture of an area or region.

The degree of uniformity of pattern may differ greatly from one soil association map to another, depending mainly upon the scale of the map. The degree of uniformity of pattern or the elements common to all areas of a soil association may be many or they may be few. On the map of a large country, the degree of uniformity within each soil association is commonly low if some 25 or 30 areas are outlined. On the other hand, the degree of uniformity in each association is relatively high in a map showing 25 or 30 associations in a county covering 1,000 square kilometers. Thus, the size of the total area to be shown at a given scale largely fixes the degree of detail possible in delineating soil associations.

2. Detailed soil surveys should then be made of carefully selected sample areas of the major associations outlined in the mapping programme. These might cover anywhere from 1 to 30 square miles. In each association of importance, the size and number of the sample areas will depend upon the variability in soil pattern in the area. During the

course of these detailed surveys, the classification of the soils into types and phases should be developed. Concurrently with the mapping of the sample areas, investigations should be carried on so far as feasible to determine the properties of soils and their behaviour in agriculture, forestry and engineering. For convenience, however, studies of morphological, chemical and physical properties are considered in a later section of the seminar discussion.

3. As the soil surveys of sample areas are completed, keys to show the relationships among soils and groupings of various sorts should be prepared. A number of different kinds of groupings is possible, depending upon the purpose at hand. For example, soils can be grouped into series, families, and great soil groups, in order to show their genetic relationships. Soil types may be arranged in keys to show relationships in terms of drainage and parent materials. They may be grouped according to their suitability for the growing of a crop or combination of crops. For any given area, keys should be prepared to facilitate identification of the soil types and phases recognised in the survey. Groupings should also be prepared as an aid to users of the information in agriculture or forestry. This step must go beyond the limits of soil science alone and draw upon data from fields such as agronomy, horticulture and forestry. Thus, this becomes an interpretive step based, in part, upon the soil survey and, in part, upon other sources.
4. After the sample areas have been mapped, the second approximation of the soil association map can be prepared. The boundaries as first outlined can be refined in many instances, and the associations themselves can be defined much more clearly. Data from sample areas will permit far more specific descriptions as to patterns and percentages of soil types and phases within each association.

The second approximation of the soil association map can be used as one part of the basis for public planning in the use of land. It will be helpful in such planning as is required in rural zoning, for the guidance of land settlement, and in the search for possible sites for irrigation and drainage projects.

5. After the revised soil association map is available, the soil surveys should be extended over the whole region as rapidly as the knowledge of the soils and the available funds will permit. It will probably be true, without exception, that available funds will not permit the mapping of soils of an entire country or district within a short space of time. Moreover, it will certainly be true, without exception, that the adequacy of surveys depends at all times upon the results of other types of research, research that may not be completed for a number of

years. The first detailed soil surveys are commonly more useful in pointing out major research problems than in solving those problems. They will have important usefulness in a land improvement programme, to be sure, but they will also be found inadequate for a number of purposes in the future as a programme of soil research goes forward. Consequently, it would not be desirable to outline a programme for the complete mapping of a country or district within a few years, even though funds might be obtainable. Areas for soil surveys should be selected on the basis of need and interest. As these surveys are made, it is of extreme importance that investigations to determine the characteristics and behaviour of the soils accompany the mapping programme. Research on the properties and responses of soils to management should go forward at the same time as do the programmes of soil classification and mapping.

On the basis of reports prepared by the various governments for this conference, it seems clear that the present knowledge of soils ranges from fairly complete information in some areas to very sketchy information in others. Consequently, all the steps outlined in the preceding paragraphs will probably be apropos in only a few places. In most instances, however, the present stage in the soil mapping programme will fall somewhere within the range of the outlined steps. Hence, the mapping programme under way can be viewed in terms of the suggestions offered to see whether or not they promise to be helpful.

#### Research on Soil Characteristics

The discussion of the research needed to characterise and define soils is separated from those of classification and mapping simply as a matter of convenience. Too much emphasis cannot be given to the need for conducting the different segments concurrently as fully as possible, so that each may have the benefit of progress in the others.

A part of the job of defining and characterising soils is carried on in conjunction with mapping. Studies of morphology require field work, and this can ordinarily be done best while the field scientists are carrying on their mapping operations. Occasionally, it is feasible to have specially trained scientists study soil morphology, but as a general rule most of the field men must also be morphologists. It is of the first importance in studies of soil morphology that the notes taken by the investigators be referred to a standard nomenclature. If that is done, the observations are more easily understood by other investigators, and there is more effective transfer of information. Considerable progress in standardisation of nomenclature for colour, structure, consistence, and the like has been made in the United States during the past ten years. Some of the work may have application elsewhere. Whatever standards may be selected for morphological descriptions of soils, however, some set of standards that is generally

available should be used, so that other investigators will not have to depend simply upon the ordinary meanings of words. Those meanings are seldom specific enough for accurate description. Along with the field notes on morphology, it is also extremely helpful to obtain good photographs of soil profiles wherever that may be feasible.

Some of the characteristics important to the classification and behaviour of soil must be measured or evaluated by means of instruments. In some instances, it is possible to bring the instruments out of doors and make evaluations in the field. For the most part, however, it is necessary that samples of soils be carried to the laboratory for the making of necessary analyses. Regardless of the kinds of determinations to be made, it is essential to conduct laboratory investigations to supplement those possible in the field. As a rough guide to a possible order of magnitude of such investigations, I might mention the fact that our plans call for expenditure of about one-fifth of the available funds on laboratory work in the soil survey programme of the Missouri River Basin.

The required laboratory determinations will vary from one place to another with the nature of the soil. Nevertheless, it is useful to have certain background information about important soil types representing great soil groups or families. Information of this kind should be obtained for carefully selected samples from which it could be projected to other similar soils. The laboratory investigations falling in this class would be determinations of chemical composition and mineralogical composition, mechanical analyses, base exchange relations, and the nature of the soil population. Determinations of chemical composition would include amounts and forms of organic matter and nitrogen, amounts and forms of phosphorus, amounts and forms of potassium, and the quantities of other elements ordinarily estimated through fusion analyses. Similarly, it will commonly be useful to have information on representative soils to give the approximate mineralogical composition of the sand, silt, and clay fractions, especially the last. The nature of the clay minerals has considerable significance to many other soil properties and is extremely useful information. Most of these analyses, however, cannot be conducted generally as a routine part of soil surveys. Some of the determinations, e.g., mechanical analyses, base exchange relations, and reaction, can be made for large numbers of samples.

The significance of data will depend upon the kinds of soils. Properties significant for some soils are not necessarily significant for others. For example, Chernozems are much less strongly weathered than Red-Yellow Podzolic soils in the United States. Changes that have occurred in mineralogical composition during horizon differentiation are minor as compared with those in Red-Yellow Podzolic soils. For that reason, properties selected for study in the laboratory are somewhat different for the two groups of soils.

A knowledge of the characteristics of soil is just as important in understanding their behaviour as it is to their proper classification and mapping. For example, I have seen liming materials used on soils that are neutral to slightly alkaline in reaction and that have high base status without exception. Knowing that about the characteristics of the soils, I am certain that the liming material is not going to be helpful, and that it may even be harmful. As another example of the importance of the knowledge of soil characteristics to the understanding of soil behaviour, I might mention the fact that we knew for some time that alfalfa seedlings could be established without lime on certain soils in western Iowa, but not on morphologically similar soils in eastern Iowa. Ultimately, we learned of slight differences in base saturation. Evidently, the critical level in base saturation fell between the values for the two soils. These examples illustrate the usefulness of a knowledge of soil characteristics in understanding soil behaviour under crops, grasses or trees.

I should emphasise the fact that I do not know the properties or characteristics that should be selected for complete characterisation of soils in Caribbean lands. I do feel certain that the same ones cannot be used for all soils in the region. Although I think that some of the properties important in characterising soils of the United States will also be significant here, I should certainly expect that additional properties might have meaning, and that some important to some of the soils in our country will have little significance. By and large, the selection of laboratory analyses for soil studies and the subsequent interpretation of the data will be just as good as and no better than the general background of understanding of the scientists responsible for them. Furthermore, the theories of soil genesis held by soil scientists largely outline the areas within which their minds work. Thus, the background in soil science and theories of genesis will largely govern the selection of analyses to be made, and will also predetermine their usefulness.

The facilities for research on soil characteristics may often be a limiting factor in the conduct of investigations in the Caribbean region. Consequently, it will seldom be possible to make all types of determinations that might be useful. It might even be impossible to make some of the determinations which could be expected to be highly significant. Hence, it may generally be necessary for the scientist to settle for something much less than ideal. Perhaps it would be useful to set down the kinds of investigations that would be desirable as if they were all possible. Next, the kinds of information could be ranked according to comparative importance in the classification of soils and in understanding soil behaviour. Finally, then, the research on soil characteristics should be directed towards collection of data that seem to be of first importance in the area, and which can be obtained with the available resources in equipment, funds and personnel.

Research in Soil Management and Productivity

Our primary interest in soils is due to their capacity to produce plants that we can use in one way or another. Thus, a large part of the research is ultimately directed towards understanding the behaviour of the soils in agriculture and forestry. The behaviour of soils in engineering is also important to us, but less so in a land improvement programme. Determining the behaviour of the soils in agriculture and forestry requires research in soil management and on soil productivity. As indicated earlier, this will call for the cooperation of scientists from several fields before the significant questions can be answered properly. What is the response to management of the soils as they are classified and mapped? What data are needed for the making of sound predictions of yields and quality of plants and of the effects of use of the soils on their characteristics? As a matter of convenience, research to answer these and similar questions is generally broken down into a number of segments.

Studies in soil management will need to deal with fertiliser, fertility levels, fertility improvement and fertility maintenance; with the management of organic matter in soil; with water relations in plant growth, drainage, irrigation and run off; with tillage practices; and with some elements of silviculture. Part of these investigations are traditionally handled by soil scientists in the United States, others are handled cooperatively by soil scientists and other investigators, and still others are handled by other groups of workers, such as foresters. However the work may be done, the greatest accomplishments will be possible through the cooperation of men from the several disciplines.

Close cooperation among soil scientists and foresters promises to have special significance in the Carilbean region. Much of the land is in forest now. Furthermore, the use of rotations in which trees are a part seems necessary for optimum production on a number of soils in tropical regions. How many and which soils is not yet known. Moreover, the research work necessary to investigate various types of rotations, including trees, is certain to be difficult because of the time and cost required. It is, therefore, especially important that investigations made have maximum usefulness.

It seems clear that techniques for research on tillage, fertilisation, crop rotations, and the like cannot be carried over directly from the temperate to the tropical and subtropical zones. As one example, we might cite the known beneficial effect of grasses and legumes on structure and tilth of Gray-Brown Podzolic soils. We might reason that similar effects could be expected on the Latosols and related soils in the tropics. Yet the reverse seems to be true. It appears that Latosols should not be put in grass or allowed to go to grass if that can be avoided. The soils

need to be kept in forest and under shade insofar as is feasible. Thus, methods which may be very good in cool and warm temperate zones may not be applicable in the Caribbean region.

In the soil surveys made in the United States at the present time, estimates of yields of crops are prepared for the different soil types and phases at two or more levels of management. Management must be defined in terms of use and such practices as fertilisation, crop rotations, and the like. These estimates of yields provide a summation of soil behaviour in agriculture or forestry with a single figure. They are predictions as to what a soil will produce under a defined set of circumstances. The making of predictions requires syntheses of knowledge from a number of different sources, and often requires some research over and above that which has been completed. Some of this research can be carried out in conjunction with soil survey field work. Some of it also is accomplished in the course of other types of research in soil management. Nevertheless, it is commonly necessary to give special attention to the determination of management levels and the productivity of different soils in any research programme. Knowledge of the productive capacity of soil under defined levels of management will be of the first importance in a general scheme for land improvement in the Caribbean region.

#### Proper Balance in Soil Classification and Research

To complete my seminar discussion, I should like to emphasise the importance of maintaining proper balance among the various segments of a programme of soil investigations. This is much easier said than done. There are no easy rules for achieving proper balance. Furthermore, the proper balance at one time and place may not be proper at another.

The several segments of a programme for soil classification and research should go forward so that each will support and supplement the others. There is little point in an extensive programme of soil surveys and mapping if we are unable to classify the soils on a sound basis. It is true, however, that part of the information on which classification can be based is obtained through programmes of field mapping. There is little point in a large programme of soil surveys without the research necessary to determine the response of the various soils to possible kinds of use and management. When the investigations are completed, and at the different stages toward completion, we want to be able to make predictions about the soils, their responses to management, their suitability for different uses, their probable behaviour under such use. These requirements, part of the ultimate objectives of soil science in agriculture and forestry, must be kept in mind at all times by the men who plan the programmes of soil classification and research.

To a large degree, the achievement of proper balance in soil re-

search programmes, as in other lines of work, will rest upon the insight and understanding of the people responsible for them. Nevertheless, the need for proper balance among the various segments of a research programme, including all fundamental and applied investigations, is so great that it can scarcely be overemphasised.

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## 2. Land Classification in a Caribbean Land Improvement Programme

By R.D. Hockensmith

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An understanding of the land is a basic factor in formulating and carrying out a complete land improvement programme in the Caribbean Area. Before specific plans for developing, improving and protecting the land resources can be intelligently worked out, basic information of a scientific nature must be obtained, classified and interpreted.

This task may for convenience be looked upon as consisting of three activities, as follows :

- (1) Soil surveys
- (2) Land-capability surveys and classification
- (3) Economic land use classification

My remarks will deal primarily with item (2) on land-capability surveys and the classification of land according to its capability. The first and third items are to be discussed by other speakers.

In the land-capability classification many land characteristics in addition to the soil are considered. Some of these additional characteristics are slope, erosion, overflow hazard, stoniness, drainage, salinity and climate. In classifying the land, each land characteristic is considered in relation to others.

Before land can be classified, the facts about land must be obtained in the field. This is done by skilled soil scientists. Here is the usual procedure a soil scientist follows :

He walks over the ground and observes the lay of the land. He bores or digs numerous holes deep enough to examine the topsoil and subsoil. Wherever necessary, he bores deeper to see what is under the subsoil. He observes texture, colour and thickness of the topsoil, nature and thickness of the subsoil, depth of useful soil material, and other characteristics. He estimates the permeability of subsoil and substratum, capacity to hold available moisture, and often the inherent fertility. He measures or estimates the soil reaction if differences occur in the area where he is working. He notes, insofar as he can, the presence of salt accumulations, degree of wetness, and existence of overflow hazards. He measures the steepness of slope. He observes the degree of soil erosion. He notes also whether the land is used for crops, pasture or woodland. He records these and any other significant land facts on a base map, which is usually an aerial photograph of sufficiently large scale to show clearly the significant land separations.

The land characteristics most often mapped in the land-capability surveys are listed in the Guide for Soil Conservation Surveys, processed by the Soil Conservation Service, U.S. Department of Agriculture, May, 1948.

### Land is Classified

A land-capability classification is the work of a group of specialists. A man trained in soil science maps the land facts as has just been described. The same man or another determines significant features of the vegetation. The combined judgment of several persons, including agronomists, engineers, foresters, range men, biologists, soil scientists, and soil conservationists who are experienced in farm or ranch conservation planning, is utilised in the process of classifying land according to its capability. These specialists consult with practical farmers or ranchers and study the results of experimental work. They consider the climate of the area. The resulting land-capability classification represents the combined opinions obtained. It is an interpretation of available facts, especially of the way land characteristics affect physical capability of the land for cultivation, grazing, forestry and wildlife.

As a rule, the same technical people with the help of practical farmers also work out recommendations about (1) How each kind of land may be used safely; and (2) the practices needed on each kind of land to maintain and improve it under the common safe uses.

Both the classification and the recommendations are made by joining land facts with research findings, technical information, and practical farm facts for convenient use. The purpose in writing the recommendations (technical guide) is to set down in convenient form the right combination of uses and practices that suits best each particular kind of land. The technical guide is an aid in making full use of the land's productive capacity without waste or impairment.

### The Classification Scheme

The group that is to classify land capability can begin work soon after the soil scientist has mapped enough land to know the principal soils, slopes, and other physical land conditions. One necessary step is to group the land-mapping units into land-capability units.

Each land-capability unit consists of the land within specified limits of soil, slope, degree of erosion, and other physical land characteristics. Land in a land-capability unit is essentially uniform with respect to physical features, including climate, which affect the crops or other plants that can be grown, and the responses of crops or other vegetation to management. All the land in a land-capability unit has about the same susceptibility to wind or water erosion under the same kind of cover.

Essentially similar cropping systems or other land-management systems are applicable throughout the unit. Land-capability units are the physical land-treatment units as far as permanent, mappable land features are concerned. Each one has nearly uniform use possibilities and conservation needs. A land-capability unit may consist of a single land-mapping unit or of several.

Land-capability units are the units of land-capability classification. They are grouped in successively broader categories where such grouping serves a useful purpose: first, into land-capability subclasses, each of which includes land having about the same kind and degree of permanent limitations; then into the eight land-capability classes, according to the degree of permanent limitations; and, finally, into the two major divisions, which are land suited for cultivation and land not suited for cultivation. The resulting classification is helpful in selecting land uses that are safe from the conservation standpoint and adaptable to the land; in selecting and applying an effective combination of soil conservation practices; and in making all necessary land-management decisions.

A farmer or rancher is concerned primarily with the land-capability units that make up his land. They are the practical land-management groups determined by permanent physical land characteristics. He is usually interested also in the eight land-capability classes. They are especially useful to show quickly the safe land uses and the approximate degree of difficulty involved in safe management. Subclasses, which are intermediate groupings between the eight classes and the specific units, are sometimes useful to show in a general way the suitable land use and the kind of management and conservation needed. A person concerned with the entire scheme for classifying land will want to examine all the categories in the classification scheme. Probably we can see the whole scheme easily if we look first at the most general category. The most general step in the classification is a separation of land suited for cultivation (from a physical standpoint) from that not suited.

#### Suitability for Cultivation

Cultivation is used broadly throughout this paper to include all culture that involves tillage of the soil every year or, in the case of certain crops, every two or three years. The distinction between land suited and land not suited for cultivation, which is required as the most general step in the classification, requires certain assumptions. These assumptions also apply in the separation of land according to degree of suitability for cultivation, grazing or forestry in the eight land-capability classes. The principal assumptions in this connection are:

1. Suitability for cultivation includes suitability for use of machinery that is common in a given country or territory for such operations as tillage and harvesting.

2. Suitability for cultivation, grazing or forestry is judged in relation to safe use of land; that is, to management that permits use of the land without significant permanent damage.
3. Suitability for cultivation, grazing or forestry includes an expected return greater than the labour, materials and other inputs needed for such use. Although the returns cannot be evaluated for this purpose in strictly quantitative terms, the expected level as a rule is correlated with one or more of the mappable land characteristics that are used directly in differentiating land-capability units.
4. Characteristics that make land difficult to manage, such as heavy texture, are significant in the land-capability classification, as well as those that affect land permanence.

The classification made under these assumptions and according to the principles stated in this paper is one that applies in a practical way to the land-use situation in the United States in the middle of the twentieth century. In another country or territory at the same time, or in the United States at some future time, different assumptions might be required to give a classification that is practical and workable.

Land suited for cultivation from a physical standpoint under these assumptions is workable, not too steep, not too wet, and not too severely limited by climate or other factors. Wherever the limitation of an arid climate is removed by irrigation, however, the land is classified according to its suitability for cultivation, grazing or forestry as determined by the factors other than climate. Limiting values of the different factors cannot be set up uniformly from place to place because the significant relation is that of the combined physical land factors to safe, long-time land use. In some places, for example, a slope of ten per cent is too steep for cultivation. Elsewhere, in a different environment, slopes of twenty per cent or more can be cultivated safely.

Any one or more of the physical land factors, including climate, can limit land so much that it is not suited for cultivation. In classifying land capability, two questions are considered. One is the degree to which the risks of water erosion, wind erosion, or other land damage limit the chances of safe, long-time land use. The other is the limitation of practicable land use by such factors as climatic hazards not correctible by irrigation, soil limitations of tight subsoil or shallow depth, stoniness that interferes with cultivation, or other inherent, permanent limitations of the land.

Most of the land not suited for cultivation under these specifications is suited for and will produce some form of permanent vegetation.

Eight Land-Capability Classes

In the second highest category of the classification, each of the two major subdivisions contains four land-capability classes. These eight land-capability classes give a simple land classification that is useful for many purposes. The eight classes, however, are too general for many specific recommendations about management and treatment of land. The eight classes are distinguished from each other according to the degree of inherent, permanent limitations or risks involved in land use. Land in each class is distinguished by a particular set of physical characteristics. Limits of the eight classes are determined by the degree to which the land characteristics are limitations to land use or land permanence. Land-capability classes are shown by standard colours on farm maps and in publications.

Subclasses and Units

Subclasses are convenient groupings of the land-capability units within one land-capability class. A land-capability class is determined by the degree of the total limitations in land use and risks or hazards to land permanence. Within one land-capability class the subclasses are determined by the kind of limitation. For example, within class III land, suited for cultivation but subject to severe limitations or hazards, we have sloping land subject to water erosion, naturally wet land that produces crops only if drains are maintained, and several other subclasses. Each of these is class III land, subject to a different kind of limitation.

On many small areas, such as a single farm, the subclass category need not be used. The soil conservationist working with a farmer generally prefers to designate the land-capability units, and the land-capability class to which each unit belongs. Thus the land operator sees directly the land characteristics and their meaning in terms of land limitations. Whenever the area considered is diverse enough to take in two or more kinds of limitations within one land-capability class, an arrangement by subclasses is helpful for many purposes. Subclasses are useful, for example, in estimating quantities of conservation practices needed. The conservation needs of class III flat, artificially drained land are very different from those of moderately sloping class III land subject to water erosion. Subclasses are generally more useful in dealing with land information over a broad, diverse area than in dealing with a single farm or a small area.

An outline of the entire scheme of classification is given in Table I.

The classification is one of land-capability in a broad sense. The objects classified are land-capability units, which are defined as essentially uniform in permanent physical characteristics. The physical

characteristics of a land-capability unit include kind of soil, slope, degree of erosion, climax vegetation, climate, and any other characteristics that are associated with hazards to crops or land, such as periodic overflows. If all are favourable, and none acts to limit land use or endanger land permanence, the land has broad capability. One or more limiting factors, such as slope, shallow soil, wetness or subhumid climate, makes the land less capable for all-around use.

### Land-Capability Classes

The eight land-capability classes are the members of the second most general category in the classification scheme. These classes of land differ from each other because of their permanent physical land features that limit land use or impose risks of erosion or other damage.

The classes range from class I to class VIII, inclusive. Class I contains the most widely adaptable land, which can be farmed easily. The other classes through class VIII are characterized by successively greater degrees of permanent limitations.

#### Land suited for cultivation

CLASS I. Land subject to no or very slight permanent limitations in use or risks of damage because of permanent land characteristics; very good land that can be cultivated safely with ordinary, good farming methods. It is nearly level land with deep, productive, easily worked soils, and is not subject to more than slight water or wind erosion. It is well drained and is not subject to damaging overflows. Class I land is productive cropland that is suited for intensive cropping use, such as production of corn and other intertilled crops.

Class I land used for crops, like all cropland, needs practices to maintain soil fertility and soil structure. Such practices often involve use of fertilisers and lime, cover and green-manure crops, crop residues, and crop rotations.

CLASS II. Land subject to moderate limitations in use, or moderate risks of damage, because of permanent land characteristics; good land that can be cultivated with easily applied special practices. The limitations of different kinds of class II land include: (1) gentle slopes; (2) moderate susceptibility to erosion; (3) soils of only moderate depth; (4) somewhat unfavourable texture and workability; (5) moderate alkalinity or salinity, easily correctible but likely to recur; (6) occasional moderate overflows; or (7) moderate wetness correctible by drainage but existing permanently as a land limitation. These are examples; the list probably is not complete. Each of these limitations requires attention on the part of the land operator. The limitation sometimes gives the farmer less latitude



in choice of crops or of management methods; or requires special practices such as soil-conserving rotations, water-control devices, or tillage methods, to name only a few of the many possibilities.

Land subject to permanent limitations or risks of damage ordinarily needs a combination of practices. For example, the class II land that consists of gently sloping deep soils subject to moderate erosion probably needs several of the following practices: terracing, strip cropping, contour tillage, crop rotations that include grasses or legumes, vegetated water-disposal areas, cover or green-manure crops, stubble mulching, fertilisers, manure and lime. The exact combination of measures will vary from place to place. It depends on the characteristics of the land, including the climate; and also on the system of farming that the farmer wants to follow.

CLASS III. Land subject to severe limitations in use for cropland, or severe risks of damage, because of permanent land characteristics; moderately good land that can be used regularly for crops in a good rotation but needs intensive treatment. Limitations of different kinds of class III land include the following (the list probably is not complete): (1) moderately steep slope; (2) high susceptibility to erosion; (3) moderate overflow hazard; (4) slow or very slow subsoil permeability; (5) excessive wetness and a continuing hazard of water-logging; (6) shallow depth to bedrock, hardpan or claypan; (7) sandy, very sandy, or gravelly soil with low moisture capacity; or (8) low inherent fertility. The foregoing list is one of general indicators, not specific guides. Land-capability significance of the factors listed varies somewhat according to climate and other influences.

Class III land is more limited by its permanent natural characteristics, or is subject to greater risks, than class II land. Limitations of some class III land restrict the choice of crops or the timing of such operations as planting and tillage.

CLASS IV. Land subject to very severe permanent limitations or hazards in use for cropland; fairly good land that is best maintained in perennial vegetation but can be cultivated occasionally or in a limited way if handled with great care. Its cropping use is limited by natural permanent features, such as slope, erosion, unfavourable soil characteristics, or adverse climate. Much class IV land in the humid regions is suited for occasional cultivation. On it the farmer can safely use a long rotation of a grain crop every 5 or 6 years, followed by several years of hay or pasture. Some of the nearly level, imperfectly drained land classified as IV is not subject to erosion, but is unsuitable for intertilled crops because of the time required for the soil to dry out in the spring, and because of its low productivity when in these crops. Choice of crops is often limited also. Some class IV land is suited only for certain specialized crops.

Land not suited for cultivation

CLASS V. Land not suited for cultivation but suited for permanent vegetation, grazing or forestry, with few or no permanent limitations and not more than slight hazards. Cultivation is not feasible because of one or more factors, such as permanent wetness, stones, or some other limitation. The land is nearly level and not subject to wind or water erosion. Grazing use or forestry use is governed by the requirements for maintaining good vegetation. Certain range-management or woodland-management practices, such as stocking within carrying capacity and control of burning, are always needed to obtain satisfactory production. Class V land on which vegetation has become temporarily depleted through misuse may require moderate or even severe restrictions in grazing or woodland use for a period of time to improve the vegetation. The land, however, is not damaged easily.

CLASS VI. Land subject to moderate permanent limitations or moderate hazards under grazing or forestry use; not suited for cultivation. It is too steep, subject to erosion, shallow, wet, or dry, or it is otherwise not suited for cultivation, but with careful management is suited for grazing or forestry. Some class VI land can be tilled just enough to establish pastures; some can be used safely for tree crops if permanent cover is maintained. The restrictions commonly needed on class VI range land to maintain the soil are chiefly regulation of grazing within the carrying capacity, deferred grazing to permit growth of grass in the spring, and rotation of grazing to permit the grass to recover and form seed. Fencing, careful location of watering places, salting and herding are some of the practices necessary to use the land properly. Gullies should be controlled by diversion of water, planting, or whatever measures are necessary. Contour furrows, ridges, diversions, or water spreaders are useful on some sites to check or divert water and thereby increase the growth of grass.

Land of Class VI is capable of producing forage or woodland products under moderate restrictions. If, however, the vegetation has been depleted by mismanagement, severe restrictions in use for a few years probably are needed to permit recovery of vegetation. An example of such temporary severe restrictions would be exclusion of livestock from overgrazed class VI range land until the desirable vegetation is restored.

Class VI land as a rule is either steeper or more subject to wind erosion than class IV land. It must not be too severely eroded, however, to prevent safe use with moderate restrictions for grazing or woodland.

Pastures in humid regions on class VI land generally need liberal fertilisation and careful regulation of grazing, and many of them need liming and reseeded.

CLASS VII. Land subject to severe permanent limitations or severe

hazards under grazing or forestry use; not suited for cultivation. It is very steep, eroded, rough, shallow, dry, or swampy, or it is otherwise limited, but can be used for grazing or forestry if handled with great care. Owing to these adverse land characteristics that severely limit the growth or utilisation of vegetation, the land is generally fair or poor for grazing or forestry. Depletion of cover on rough, erodible class VII land leads to more rapid damage than on class VI land that has similar but less extreme limitations. Structures such as contour furrows, ridges, and water spreaders for the most part cannot be used on class VII range land because of steep slopes, shallow soils, or other unfavourable factors.

Most class VII land in humid regions is recommended for woodland rather than for pasture. Practices recommended for woodland usually include exclusion of livestock, prevention of fire, selection of trees for cutting, and careful harvesting methods. Most of the severely gullied land in humid areas is class VII land that should be planted to trees.

CLASS VIII. Land that has some limitation that makes it unfit for cultivation, grazing or forestry. It is suited for wildlife, recreation, or watershed uses. It includes such areas as marshes, deserts, badlands, deep gullies of the caving type, high mountain land, barren land, and extremely steep or stony land. Class VIII land often occurs in small areas, such as roadsides or ditch banks, that cannot be shown on the maps made for farm planning. Protection is necessary for some of these areas.

#### Permanent Land Limitations

Land factors used in the land-capability classification are those which limit land use or impose risks of erosion or other damage. Only permanent land features affect the classification. Slope, for example, is one factor that limits safe land use. Arid climate is another. Soil limitations, such as textures too fine or too coarse, or a shallow depth of useful soil material, are other examples. Temporary features, such as present vegetation, do not affect the land-capability classification. Land in any one of the classes suited for cultivation may be covered at present with trees, stumps, or brush, or may be without cover. The soil may be depleted or in poor structural condition. Temporary limitations, of course, are of extreme importance in making immediate land-management decisions, although they do not affect the land-capability classification.

Restrictions in grazing use are often mentioned in management of ranges and pastures. Temporary restrictions in number of livestock in order to improve condition of vegetation are not considered in the land-capability classification. After a permanent range has been brought to excellent condition, however, the restrictions needed to keep it there would be considered in the classification.

Use of Land-Capability Maps





The farmer has in his land-capability map a written record of the land conditions on his farm. With a knowledge of land conditions and land capability, he has information to help him make production adjustments. His very good, nearly level land can be used most often for crops. His steeper, more erodible, or other less desirable land can be used for hay, pasture, shrubs or trees. Often class III land that is moderately steep and subject to erosion will give better returns from grasses or legumes than from annual crops.

Capability of the land affords a sound basis for agricultural credit. Land farmed with regard for its inherent limitations is a better credit risk than land farmed beyond its capability. Lending institutions can encourage conservation and discourage misuse of land.

Capability of land is of interest to many public agencies and to business concerns. Extension of roads, electric lines and other improvements often can be planned with greatest efficiency if information about capability of the land is available. Often tax assessments can be guided by the nature of the land and its capability classification. Usually for such purposes information is needed about land-capability units or at least about the subclasses within the eight land-capability classes.

TABLE 1

OUTLINE OF THE LAND-CAPABILITY CLASSIFICATION

Major Land-Use Suitability  (Broad grouping of limitations)	Land-Capability Class  (Degree of limitations)	Land-Capability SUBCLASS (Kind of limitations)  (Groupings of land-capability units. Examples of possible subclasses in class III:)	Land-Capability Unit (Distinctive physical characteristics)  (Land-management groups based on permanent physical factors. Example)
Suited for cultivation.	<input type="checkbox"/> I Few limitations. Wide latitude for each use. Very good land from every standpoint.		
	<input type="checkbox"/> II Moderate limitations or risks of damage. Good land from all-around standpoint.		
	<input type="checkbox"/> III Severe limitations or risks of damage. Regular cultivation possible if limitations are observed.	 Limited by hazard of water erosion; moderately sloping land.	13-C-2 Moderately sloping slightly acid soils on limestone.
		 Limited by excess water; needs drainage for cultivation.	9-C-2 Moderately sloping highly acid soils on sandstone or shale.
		 Limited by low moisture capacity; sandy land.	
		 Limited by tight, very slowly permeable subsoils; claypan land.	
<input type="checkbox"/> IV Very severe limitations. Suited for occasional cultivation or for some kind of limited cultivation.			
Not suited for cultivation; suited for permanent vegetation.	<input type="checkbox"/> V Not suited for cultivation because of wetness, stones, overflows, etc. Few land limitations affect grazing or forestry use.	Groupings of range, pasture or forest sites.	Land-management groups based on permanent physical factors, such as range sites or forest sites.
	<input type="checkbox"/> VI Too steep, stony, arid, wet, etc., for cultivation. Moderate limitations for grazing or forestry.		
	<input type="checkbox"/> VII Very steep, rough, arid, wet, etc. Severe limitations for grazing or forestry.		
	<input type="checkbox"/> VIII Extremely rough, arid, swampy, etc. Not suited for cultivation, grazing, or forestry. Suited for wildlife, watersheds, or recreation.		

### 3. A Land Classification Programme for the Caribbean Area

By A.B. Lewis

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Dr. Hockensmith has already referred in his remarks to economic land use classification as one of the phases of a land improvement programme for the Caribbean Area. On my part, I should like to outline for you briefly the history of the development of economic land use classification and the functions it performs.

Economic land use classification grew out of the science of farm management, which, in turn, originated as a result of the earliest soil surveys. Shortly after 1899, when soil surveying in the United States first began, a soil survey was completed by the United States Soil Survey in Wayne County, New York, a county where apples were a principal crop. The New York State College of Agriculture at Cornell University immediately took an interest in this soil survey and the possible relation of the soil variations it had mapped to the yield of apples per acre of orchard land. The late G.F. Warren, who eventually became head of the Department of Agricultural Economics and Farm Management of the College, set out to collect data in the field on the yield of apples as related to the soil types. This was the first attempt to gather farm data, to be subjected to statistical analysis, by the so-called "survey method", and farm-by-farm interview. Dr. Warren's conclusions, by the way, were that the soil types were indeed related to apple yields, and that the two factors of soil depth and soil drainage were the most important soil factors from their viewpoint.

So successful was this first "farm survey" that it was decided to apply the same method to an analysis of the complete farm business - not merely the orchard or another single enterprise. A complete farm business survey of farms in several townships of Thompkins County was attempted in 1906, but the results were never published, because an attempt was made to collect too much data and the underlying principles of farming as a business had not been well enough worked out in advance. In 1907, however, other townships in the same county were covered, and the resulting publication, Cornell Experiment Station Bulletin 295, published in 1911, is still a classic, and has since furnished a pattern for many similar studies in many parts of the world.

The original farm management survey study concerned itself to a noticeable degree with the relation of the soil types in Thompkins County, which had already had its soils mapped, and farming returns. There were statements, for example, to the effect that some soils were better suited to forests than to farms. As the science of farm management developed further, the interest of the farm management specialists at Cornell and elsewhere in land characteristics as a factor influencing farming returns was maintained. At the same time, the influence of other factors, such as size of farm, efficiency of management of labour, choice of crop and live-

stock enterprises, prices, and others, were investigated.

During the 1920's the growing areas of abandoned farms in New York State attracted wide public attention there, and the College made farm management studies of farms that were still occupied in areas where many farms had been deserted, and where buildings were falling down for lack of repairs and the land growing up to scrub vegetation or woods. Its conclusion was that the farms were being abandoned because the soils in the "abandoned-farm areas" were too poor to support agriculture of the modern type, and should be returned to forests.

There shortly followed a series of legislative enactments in New York whereby funds were provided to purchase suitable farm lands and return them to forests under State ownership, and for classifying the rural lands to determine which were best suited to this purpose. In 1930, I undertook the task, as a graduate student under the direction of Dr. G.F. Warren, of making a land classification map of Thompsons County, a county frequently chosen as a place to try out new ideas because the College is situated in its centre.

At first we had the general intention of delineating mainly the areas that were more suitable for reforestation than for farming. But we soon found that it was possible to classify the land that was suitable for agriculture into three classes. We, therefore, concluded with the map which you see here, a map classifying the land into five grades or classes on the basis of the intensity of use to which each grade is adapted, beginning with land adapted only to forestry (land class I), and ending with land adapted to intensive agriculture (land class V).

This map was based on the topographic map, the soil map (made in 1920), a land use map which we made, and a map showing a visual classification of all farms according to the amount and condition of buildings and other visible capital. Areas where nearly all farms were "poor", that is, tumbling down and growing up to trees, were tentatively outlined as sub-marginal areas for farming, with the tentative boundaries conforming with topographic changes. These boundaries were then refined and confirmed by superimposing them on a detailed land use map that had been recorded, in turn, on the soil survey map.

We have always used the soil survey maps in land classification wherever they were available, and in New York have painstakingly tabulated the relationships between the economic land classes and the soil types in the greatest possible detail. Because of differences in the point of view of the two classifications, soil type areas are often bisected by economic land use class boundaries, and many different soil types are always comprised within an economic land class area.

Since land-capability maps have become available, we have found them extremely useful in economic land classification because they already constitute an evaluation of the soil and other land factors from the viewpoint of their relation to crop growth and land treatment. The separations are, of course, very much smaller than any we make on an economic land class map, but they readily lend themselves to generalisation, and well represent, from our point of view, the physical element, as distinct from the economic element, in our economic land classification.

The farmer must use a complex of soil types and land condition in getting his living on the land, and it is this complex that is evaluated by the economic land use class map in terms of the intensity of use to which it is adapted. This means, in practical terms, how much it is worth, comparatively speaking, in the market; what comparative size of farm loan or fire insurance policy it will support; what comparative taxes it can pay; and what other services (as roads, electrification, irrigation, etc.) its production will support. Incidentally, too, the economic land classes conform to the comparative net returns which farmers earn on the land and comparative amounts of capital they can expect to accumulate on and in the farm.

Since the economic land use class areas are always large enough to include several farms, they do not furnish a complete answer to all questions concerning a single farm. The economic land use class designation applies to the average farm within the class, but there is naturally much variation between and within the individual farms. In a farm planning and soil conservation programme, for example, the agricultural officer needs a land-capability map to advise a farmer on how to rearrange his fields and cropping system, install terraces, and take other land improving measures. At the same time, this officer needs to be guided in a general way by the economic land class of the farm in making his recommendation. If, for example, the farm is an average farm in a land class where farms generally support a capital (buildings, fences, drains, land, orchards, machines, livestock, etc.) that is valued at \$8,000, the agricultural officer might reasonably suggest the construction of farm works or other capital outlays that would somewhat increase the capital value of the farm, on the basis of its expected increased earning power; but if he recommended a capital expenditure exceeding by (say) \$2,000 an upper limit of (say) \$10,000, that additional capital of \$2,000 would waste away, physically and in value terms, for lack of sufficient income to support it. On the other hand, much more expensive recommendations for improvement would be well justified for a farm in a higher economic land use class.

In a similar way, economic land use maps furnish guides for agricultural credit and taxation policies, but do not dispense with the need of individual farm appraisal and assessment as a basis for loans and levies. In individual farm appraisals and assessments, land-capability maps are useful.



In summary, economic land use class maps of territories in the Caribbean area, if constructed as part of a Land Improvement Programme for the area, would furnish the necessary basic guidance for such programmes as new land settlements, irrigation and drainage, reforestation, rural electrification, improvement of rural roads, extension of agricultural credit, extension of farm fire insurance, planning rural school systems, conservation of soil and water, and (what is extremely important) the entire agricultural extension and advisory programme. They also would serve as an indispensable framework for agricultural economics, farm management, and rural sociological research.

For the purpose of setting the standards for and evaluating the results of economic land use classification in the Caribbean, more farm management research is necessary in the area.

#### 4. Soil Conservation in Puerto Rico and the Virgin Islands of the United States

By U.S. Allison

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The soil and water conservation programme in Puerto Rico and the U.S. Virgin Islands is carried out through locally organised soil conservation districts. Similar programmes are in operation in each of the 48 states and in the territories of Hawaii and Alaska.

The organization and operation of the national programme of soil conservation and proper land use in the United States may be divided into four major steps. First, the enactment of appropriate legislation and the establishment of a national soil conservation organisation; second, obtaining the needed basic information through organised research; third, the development of land capability classification information; and fourth, the development of the conservation farm plan, together with on-site technical assistance in applying and maintaining the practices recommended in this plan. I shall discuss the phase of legislation and organisation, Dr. R.M. Smith will discuss the research phase, Mr. Juan P. Cordova will explain to you how we obtain land capability classification information, and Dr. Joaquín F. Marrero will explain how the conservation farm plan is developed and carried out.

At the present time, the national soil conservation programme in the United States is being carried out under the authority of an Act passed by Congress in 1935. This law authorised the establishment of the Soil Conservation Service as a scientific and technical agency in the U.S. Department of Agriculture. The functions of the Service are divided into the principal divisions of research and operations. The responsibilities and authority of the Service are defined, and provision is made for the appropriation of funds for carrying out its activities. The Service is charged with the responsibility "of providing aid in bringing about physical adjustments in land use that will better human welfare, conserve natural resources, establish a permanent and balanced agriculture and reduce the hazards of floods and sedimentation." This aid is given to the land owners and operators in the states, territories and insular possessions through the locally organised soil conservation districts.

District organisations have been established in each of the states, territories and insular possessions of the United States. They are established by and operate under authority of legislation enacted by the state, territory, or insular legislatures. The legislature of Puerto Rico and the legislative bodies of the Virgin Islands of the United States enacted such legislation in 1946. This legislation is based on "A Standard State Soil Conservation Districts Law", prepared by the U.S. Department of Agriculture at the request of the representatives of a number of States. The provisions of this standard law are adapted to local conditions by the legislatures with the assistance of qualified people working in the field of agriculture.

These soil conservation districts laws are called enabling legislation. That is, they provide legal authority for the creation of soil conservation districts. The laws themselves do not create districts. Districts are created by popular vote of the landowners and operators.

In order to explain the general procedure for creating soil conservation districts, I shall limit my discussion to the Soil Conservation Districts Act of Puerto Rico.

Briefly, this Act sets up in the Insular Department of Agriculture an Insular Soil Conservation Committee. The membership of this Committee consists of the Commissioner of Agriculture, who is the Chairman; the Director of the Insular Experiment Station; the Director of the Insular Extension Service; another ex officio member appointed by the Secretary of the U.S. Department of Agriculture; and three farmer members, who are appointed by the Governor. The principal responsibility of this Committee is to provide leadership and advice in the formation of districts and, after the districts are organized, to the supervisors of the districts. It also designates the procedure to be used in the creation of the districts, provides for the formation of a board of supervisors for each district, and defines the authority, duties and responsibilities of the Boards of Supervisors.

Under the provisions of this Act, the Insular Soil Conservation Committee, with the assistance of qualified people in the field of agriculture, and with the approval of the Planning Board, established the boundaries for 17 proposed districts. Following this action, the Committee conducted hearings in each of these areas to determine whether a need existed for the creation of such districts. Public sentiment was overwhelmingly in favour of the creation of districts. Therefore, a referendum was held in each of the designated areas.

In these referenda, landowners and operators had the privilege to vote for or against the creation of a district. A majority of the qualified voters in each of the 17 proposed districts voted for their creation. At the same time that the voters expressed their opinion concerning the creation of the district, they voted for three members of a five-member board of supervisors. The other two members of each board were later appointed by the Insular Soil Conservation Committee.

Each of the soil conservation districts thus created, by popular vote of qualified voters, is a governmental subdivision of Puerto Rico and a public body corporate and politic. The districts are created by the democratic process of the landowners and operators expressing their opinions in secret ballot, and they are governed in the democratic way by the three farmer members elected by popular vote and the two farmer members appointed by the Insular Committee. The districts are not controlled by any federal or insular agency or bureau, and their actions are subject only to the desires of the landowners and to the laws of Puerto Rico.

The boards of supervisors do not have the authority to force any landowner or operator to carry out a conservation programme on his farm. They are merely an instrumentality through which the farmers in each district may seek and obtain assistance from insular and federal agencies, or from any other source, in carrying out a soil and water conservation and proper land use programme on their farms. Although there is no compulsion in the soil conservation districts law, it does make provision for the adoption of land use regulations. The procedure for adopting such land use regulations is for the board of supervisors in a district to conduct a referendum for the purpose of submitting to the land occupiers, for their approval or disapproval, regulations governing the use of land within the district to conserve soil and water resources and to prevent and control erosion. Unless at least 51 per cent of the land occupiers cast their votes in favour of the proposed regulations, the supervisor shall not have authority to enact such regulations into law.

The Soil Conservation Districts Law for Puerto Rico became effective on July 1, 1946, and elections for creating districts were completed in January, 1947. Soon after the districts were created and the boards of supervisors were organized, they petitioned the U.S. Department of Agriculture to give them assistance in carrying out their district programmes. The Secretary of Agriculture signed a memorandum of understanding with each board of supervisors of the 17 districts. Following this formal understanding, the boards of supervisors requested the Soil Conservation Service to enter into an agreement with them whereby the Service would provide on-site technical assistance to the land occupiers in each of the districts. By July 1, 1947, the Service had signed an agreement with each Board of Supervisors in Puerto Rico and had provided trained technicians for each district to give the farmers the assistance needed.

Before a land occupier can obtain assistance from Service technicians, however, he must make a formal request to the Board of Supervisors of the district in which his land is located. The supervisors, with the assistance of other agencies and conservation-minded farmers, hold community meetings at which the benefits of the programme are explained. If a majority of the farmers make application to join the district programme, the community is approved by the Board and the individual applications from the farmers are accepted. The Board then requests the Service to give on-site technical assistance to the farmers who made application. The Service makes the land capability survey of each farm, as will be explained by Mr. Cordova. After the land capability information is obtained, Service technicians assist the farmers in developing a conservation farm plan for each farm, and also give on-site assistance in the application and maintenance of recommended conservation and land use practices. This phase of the work will be explained by Dr. Marrero.

## 5. Soil Conservation in Puerto Rico : The Function of Research

By Richard M. Smith\*

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The research project which I represent was established about three years ago. Its primary objective was to provide information needed by the action programme of soil conservation in Puerto Rico. This action programme, as explained by Mr. Allison, is implemented through the democratic organisation and democratic control vested in Soil Conservation Districts.

In order to take advantage of technical knowledge, skill and facilities wherever these were available, this project was set up involving cooperation among the Puerto Rico Agricultural Experiment Station, the Soil Conservation Service, the Bureau of Plant Industry, Soils and Agricultural Engineering, and the Office of Experiment Stations.

Activities of the project include grass and legume breeding, forage management, soil and crop management, and studies of irrigation and water use by crops. However, since this is a soils conference, and since our ultimate objective is to preserve or increase the productivity of soil, I would like to centre attention on soils and soil properties with only casual mention of other aspects of our work.

This project was set up and operates on the theory that research problems originate on the land in connection with practical farm planning rather than in the minds of research workers at distant locations. At the same time we believe that practical farm problems can be solved efficiently and permanently only by seeking fundamental information and understanding which permit the establishment of general principles of wide application. In this way there is hope of giving to field technicians and to farmers a firm basis on which they can build appropriate conservation and production procedures to fit individual farm needs.

An essential part of our work is understanding soil profiles. We do not map land, but we must understand what is mapped. Furthermore, we must understand in such a way that our concepts can be transferred to farmers and to field technicians. The problem is one of maintaining fundamental soundness on the one hand, yet of providing a medium of transfer and interpretation for practical use on the other.

Our overall approach, therefore, involves knowing from contact with farmers what the problems are; of converting those farm problems into the type of question which lends itself to scientific investigations; of investi-

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\* Project Supervisor of RM PROJECT 74, "Erosion Control and Stable Crop Production in Puerto Rico".

gating in such a way that we gain a real practical understanding of the answer; and of being sure what the true conditions are at experimental locations as well as on farms, so that the answers can be properly interpreted and applied back to the land where the problem originated. Also, since our problems originate on farms, we look first to farms to find what practical soil properties need consideration. An expression of these properties in practical terms, is outlined below :

Soil Properties Which Directly Influence Land Capability:

I. Mechanical Properties

1. Profile Depth - effective
2. Workability
3. Erodibility

II. Water Properties

1. Intake Capacity (Infiltration)
2. Transfer Capacity (Percolation)
3. Holding Capacity

- a. Amount available
- b. Tightness held

III. Aeration Capacity

IV. Plant Nutrient Properties

1. Acid Intensity (pH)
2. Acid Quantity (Lime requirement)
3. Available nutrients
  - a. General fertility
  - b. Specific fertility - individual elements
4. Soluble Salts - toxic influences

Referring first to mechanical properties, it seems that practical soil use could hardly avoid a consciousness of soil depth, of workability, and of the tendency of soil to be removed by running water, wind or gravity.

As regards water, this essential substance must enter the soil surface and it must move within or through the soil profile. Also, for water to support growth, it must be held. This holding obviously involves quantity as well as intensity of the forces involved.

Aeration we have expressed as a capacity. The practical idea is to know whether gaseous exchange is adequate or limiting for maximum growth of desired crops.

Finally, the very broad term, "plant nutrient properties", is suggested to cover the quantity and the intensity features of soil acidity, the general and the specific presence of adequate plant nutrient elements, and the presence of soluble salts, which might be detrimental in a way which is independent of available nutrients.

Having decided what practical properties may be directly important in soil use on farms, our problem is to define and to understand these properties. The understanding may require much or little effort depending on circumstances. Our ideal is to be able to obtain some specific means of measuring and expressing each property in terms which cannot be confused. This, of course, is not always possible in our present state of knowledge, but I think research is making considerable progress in that direction. Details of how we are attempting to apply measured values and well calibrated observations to express these properties are explained in a paper presented jointly with Dr. George Samuels to this Conference. At present our best index of some properties is observations, but we would prefer to substitute a measured value for even an experienced opinion whenever possible. However, unless the measured value is of proved accuracy and meaning, there is no justification for accepting it in preference to the experienced interpretation of a field scientist.

Now, on this base of soil properties I would like to indicate a few of the effects of accelerated soil erosion which we have studied in Puerto Rico. These effects are, of course, entirely separate from the influence which different degrees of geologic erosion may have had upon original soil development and original soil depth. The rate of geologic erosion is normally much slower than the rate of soil removal under cropping even when good conservation practices are applied.

When deep, reddish upland clay soil (Catalina and similar soils) erodes, the major properties suffer. First, there is a heavy loss of surface soil organic matter and nitrogen. This reduces the capacity of the soil to supply essential nutrients, and it may intensify the damage done by acidity. Associated with the surface, also, is a well formed, water stable structure. This is not true of the underlying horizons. Loss of the surface, therefore, permits the clay texture to assert itself. The practical factor of workability becomes such that satisfactory tillage is very difficult or impossible. We have had this experience with desurfaced, runoff-erosion plots and with a number of constructed bench terraces. Without a surface horizon the soil is useful mainly for permanent vegetation only, and growth of any kind is good only when nitrogen and other nutrients are supplied. Water intake is also likely to be retarded and erodibility is defi-

nitely increased.

If we consider next the shallow brown clay mountain land of the interior, which predominates over most of the large area shown on the map, we find different capability limitations and new dangers. The shallow rooting zone and the low available water holding capacity already limit soil use. Any reduction by erosion would severely limit crop yields regardless of other factors. Again, too, organic matter in the surface provides workability and essential plant nutrients. With this kind of land the damage by any degree of erosion is very severe, and is so obvious that it hardly needs further discussion.

One more contrasting example which we have studied is the Utuado sandy soil derived from granitic rock. In this case the rock is rotten to great depths and the workability of exposed subsoil or rock is excellent, much the same as in the surface. However, the topsoil contains about 4,000 pounds of total nitrogen per acre, and has a permanent available water holding capacity of about 10%, compared with less than 0.1 as much nitrogen and  $\frac{1}{4}$  as much water holding capacity in the subsoil. The economic loss, therefore, is heavy when the surface soil is carried away. But favourable workability and fair mineral fertility might permit the use of this land forever at a rather low productive level in spite of considerable erosion.

I hope that these few illustrations serve to show how our research work fits into the overall programme of soil conservation and proper land use in Puerto Rico. With soil properties plus other environmental factors as the foundation for research, the ideal medium for transferring research information into practical recommendations appears to be some sort of a physical inventory of land resources of farms where the programme is being applied. For discussion of how this is accomplished, I am happy to refer you to Mr. Cordova, who follows me on this programme.



## 6. Land Capability Classes as a Factor in Determining Land Use in Puerto Rico

By Juan P. Cordova

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Land can be classified in different ways and for different purposes.

Because of the needs of classifying soils according to their potentialities, limitations and needs, the land capability classification was started by the Soil Conservation Service in 1939. The land capability classes represent the summarisation for a more practical use of the interpretation of the land facts recorded in the soil conservation surveys.

Soil, slope and erosion are the most important land facts taken into consideration for making a soil conservation survey.

1. **Soil Mapping Unit:**- Ordinarily the most significant soil characteristics taken into consideration in a soil unit are: effective depth of the soil, texture of the surface soil, and permeability of the subsoil. Other significant characteristics may be thickness of any particular surface, or subsoil layers, permeability of substratum, character of the underlying parent material, available moisture capacity, natural soil drainage, degree of acidity or alkalinity, amount of organic matter or deficiencies in plant nutrients.
2. **Slope:**- Steepness of slope, character of slope, such as length, direction of exposure and smoothness are important land features significant in the efficient use of the land.
3. **Erosion:**- Erosion as mapped gives a quantitative estimate of the changes that have occurred, gives an indication of the rate of past and possible future damages, and also shows what is left of productive topsoil.

Eight land capability classes are recognised, and they give a quick summary of the land suited for different uses. The first four classes represent land that is suited for cultivation, and classes V, VI, VII and VIII are not suited for cultivation.

### Land Suited for Cultivation

- Class I** Very good land that can be cultivated safely with ordinary good farming methods.
- Class II** Good land that can be cultivated safely with moderate conservation treatments. These include such treatments as contouring,

protective cover crops or simple water management operations. Common requirements are crops rotations and fertilisation.

- Class III Moderately good land that can be cultivated safely with intensive conservation treatments, such as terracing, strip cropping, complex water management operations. Common requirements are crop rotation, cover crops, and fertilisation.
- Class IV Fairly good land that is generally better suited to pasture or forage but can be cultivated occasionally if handled with great care. Intensive conservation treatments are needed when cultivated.

Lands Not Suited for Cultivation: Suited for Permanent Vegetation

- Class V Land best suited for grazing or forage with few or no limitations, needs only good management practices. Is nearly level, with slight erosion hazards or imperfectly drained, but not too wet for grazing.
- Class VI Land suitable for permanent vegetation, grazing or forestry with moderate permanent limitations generally recommended for grazing or close forage crops. Not too steep or eroded for establishments and maintenance of forage or grazing.
- Class VII Land suitable for permanent vegetation, forestry or grazing. Generally recommended for forestry. It is either very steep, severely eroded, very rough, very shallow, very wet, or very dry.
- Class VIII Land not suited for cultivation, grazing or forestry but may be utilised for wildlife, recreation or watershed protection.

Three sub-classes, A, B and E are recognised. Sub-class A indicates land needing drainage, sub-class B indicates land of very low fertility, and sub-class E indicates that erosion is the dominant hazard of the class.

The following pages give a more detailed description of the classes and sub-classes.

PRINCIPLES OF LAND CAPABILITY CLASSIFICATION

TABLE I

MAJOR LAND SUITABILITY	LAND CAPABILITY CLASSES	LAND CAPABILITY SUB-CLASSES	LAND CAPABILITY UNITS	
MAJOR LAND SUITABILITY	DEGREE OF LIMITATIONS OR HAZARDS	KIND OF DOMINANT LIMITATION OR HAZARDS	DETAILED DESCRIPTIONS OF PHYSICAL CONDITIONS OF EACH UNIT OF AREA TO WHICH SPECIFIC TREATMENT RECOMMENDATIONS APPLY FOR BEST SUSTAINED USE OF THE LAND	SURVEY MAPPING UNITS INCLUDED

LAND CAPABILITY CLASSES AS A FACTOR IN DETERMINING LAND USE  
IN PUERTO RICO

TABLE II

SUITABILITY	LAND CAPABILITY CLASS	LAND CAPABILITY SUB-CLASS LIMITATIONS OR HAZARDS	EXAMPLES OF LAND CAPABILITY UNITS IN PUERTO RICO
LANDS SUITABLE FOR CULTIVATION	<p>I</p> <p>LANDS WITH FEW OR NO PERMANENT LIMITATIONS, AND WHICH DO NOT HAVE HAZARDS TO THE MAINTENANCE OF THE LAND</p> <p>*****</p>	None	<p>Deep, nearly level, well drained, medium textured bottom lands</p> <p>210A0</p> <p>207A0</p>
	<p>VERY GOOD LAND THAT CAN BE CULTIVATED SAFELY WITH GOOD FARMING METHODS</p>		<p>Deep, nearly level, well drained soil with moderately heavy textured top-soil, and moderately heavy, moderately permeable sub-soil</p> <p>7A0</p> <p>284 A1</p>

TABLE III

SUITABILITY	LAND CAPABILITY CLASS	LAND CAPABILITY SUB-CLASS LIMITATIONS OR HAZARDS	EXAMPLES OF LAND CAPABILITY UNITS IN PUERTO RICO	
LANDS SUITABLE FOR CULTIVATION	II LANDS WITH MODERATE PERMANENT LIMITATIONS OR HAZARDS TO THE MAINTENANCE OF THE LAND ***** GOOD LAND THAT CAN BE CULTIVATED SAFELY WITH MODERATE CONSERVATION TREATMENT	E EROSION is dominant hazard	Deep, gently sloping, well drained, soil with moderately heavy textured topsoil and moderately heavy, moderately permeable subsoil. Slight erosion	7B1
			Deep, gently sloping, well drained soil with moderately textured topsoil and moderately light textured subsoil with moderately rapid permeability. Moderate erosion.	55B2
		A EXCESS WATER is dominant hazard	Deep, nearly level, imperfectly drained soil with medium textured topsoil and moderately heavy subsoil. Slight erosion	227A0
		B LOW AVAILABLE MOISTURE CAPACITY is dominant hazard	Deep, gently sloping, excessively drained soil with thick, light textured topsoil and moderately light textured subsoil with rapid permeability. Slight erosion	295B1

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TABLE IV

SUITABILITY	LAND CAPABILITY CLASS	LAND CAPABILITY SUB-CLASS LIMITATIONS OR HAZARDS	EXAMPLES OF LAND CAPABILITY UNITS IN PUERTO RICO	
LANDS SUITABLE FOR CULTIVATION	III LANDS WITH SEVERE PERMANENT LIMITATIONS OR FREQUENT HAZARDS TO THE MAINTENANCE OF THE LAND ***** MODERATELY GOOD LAND THAT CAN BE CULTIVATED SAFELY WITH INTENSIVE CONSERVATION TREATMENT	E EROSION is dominant hazard	Moderately deep, moderately sloping, well drained soil with thin, moderately heavy textured top and subsoil. Moderately permeable throughout. Moderate erosion	35C2
			Deep, well drained, strongly sloping soil with thin, moderately heavy topsoil and moderately heavy, moderately permeable subsoil. Severe erosion	7D3
		A EXCESS WATER is dominant hazard	Moderately deep, nearly level, poorly drained soil with heavy textured topsoil and thick, heavy, slowly permeable subsoil. Slight erosion	272A1
		B LOW AVAILABLE MOISTURE CAPACITY is dominant hazard	Deep, gently sloping, excessively drained soil with thick, very light textured topsoil and light textured subsoil with rapid permeability. Slight erosion	295B1

TABLE V

SUITABILITY	LAND CAPABILITY CLASS	LAND CAPABILITY SUB-CLASS LIMITATIONS OR HAZARDS	EXAMPLES OF LAND CAPABILITY UNITS IN PUERTO RICO
LANDS SUITABLE FOR CULTIVATION	IV LANDS SUITABLE FOR OCCASIONAL OR LIMITED CULTIVATION. HAVE VERY SEVERE PERMANENT LIMITATIONS OR VERY FREQUENT HAZARDS ***** FAIRLY GOOD LAND THAT IS GENERALLY BEST SUITED TO PASTURE AND HAY BUT CAN BE CULTIVATED OCCASIONALLY IF HANDLED WITH GREAT CARE	E EROSION is dominant hazard	Moderately deep, strongly sloping, well drained soil with thin, medium textured topsoil and moderately heavy subsoil and moderately permeable. Severe erosion 35D3
		A EXCESS WATER is dominant hazard	Deep, nearly level, poorly drained soil with thick, heavy textured topsoil and very heavy, slowly permeable subsoil 277A0
		B LOW AVAILABLE MOISTURE CAPACITY is dominant hazard	Deep, gently sloping, excessively drained, very light textured soils low in organic matter. Slight erosion 327B1

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TABLE VI

SUITABILITY	LAND CAPABILITY CLASS	LAND CAPABILITY SUB-CLASS LIMITATIONS OR HAZARDS	EXAMPLES OF LAND CAPABILITY UNITS IN PUERTO RICO	
<p>LANDS NOT SUITABLE FOR CULTIVATION</p>	<p>V</p> <p>LANDS SUITABLE FOR PERMANENT VEGETATION, GRAZING OR FORESTRY, WITH FEW OR NO PERMANENT LIMITATIONS OR ONLY SLIGHT HAZARDS FOR THESE USES</p> <p>*****</p> <p>GENERALLY RECOMMENDED FOR GRAZING OR FORAGE. INCLUDES NEARLY LEVEL LANDS WITH SLIGHT EROSION HAZARDS; IMPERFECTLY DRAINED LANDS NOT TOO WET TO USE FOR GRAZING OR FORAGE; SHALLOW SOILS OVER MATERIAL DETRIMENTAL TO ROOT AND WATER PENETRATION</p>	<p>NONE</p>	<p>Deep, excessively drained, very light textured soil, very rapidly permeable. Low in fertility. Nearly level. Little erosion</p>	<p>326A0</p>



TABLE VII

SUITABILITY	LAND CAPABILITY CLASS	LAND CAPABILITY SUB-CLASS LIMITATIONS OR HAZARDS	EXAMPLES OF LAND CAPABILITY UNITS IN PUERTO RICO	
LANDS NOT SUITABLE FOR CULTIVATION	<p style="text-align: center;">VI</p> <p>LANDS SUITABLE FOR PERMANENT VEGETATION, GRAZING OR FORESTRY, WITH MODERATE PERMANENT LIMITATIONS OR MODERATE HAZARDS</p> <p>*****</p> <p>GENERALLY RECOMMENDED FOR GRAZING OR FORAGE. TOO STEEP, OR TOO SEVERE SHEET EROSION FOR CULTIVATION; NOT TOO STEEP OR GULLIED FOR ESTABLISHMENT AND MAINTENANCE OF FORAGE AND GRAZING</p>	<p style="text-align: center;">E</p> <p>EROSION is dominant hazard</p>	<p>Well drained, shallow, moderately heavy textured soil. Steep slope. Moderate sheet erosion</p>	<p>64E2</p>
			<p>Well drained, deep, heavy textured soil. Severe sheet erosion. Steep slope.</p>	<p>39E3</p>
			<p>Well drained, shallow, heavy textured soil; strongly sloping, moderate erosion</p>	<p>23D3</p>

LAND CAPABILITY CLASSES AS A FACTOR IN DETERMINING LAND USE  
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TABLE VIII

SUITABILITY	LAND CAPABILITY CLASS	LAND CAPABILITY SUB-CLASS LIMITATIONS OR HAZARDS	EXAMPLES OF LAND CAPABILITY UNITS IN PUERTO RICO	
LANDS NOT SUITABLE FOR CULTIVATION	VII LANDS SUITABLE FOR PERMANENT VEGETATION, GRAZING OR FORESTRY, WITH SEVERE PERMANENT LIMITATIONS OR SEVERE HAZARDS	E EROSION is dominant hazard	Shallow, well drained, heavy soil. Gently sloping. Very severe sheet erosion	23D4
			Shallow, well drained soil with moderately heavy textured topsoil and moderately heavy subsoil. Slight erosion. Very steep slope	35F1
	***** GENERALLY RECOMMENDED FOR FORESTRY. IT IS VERY STEEP,	A EXCESS WATER is dominant hazard	Moderately deep, very poorly drained, very light textured soil suited only for swamp woodland	338A0
	SEVERELY GULLED, VERY ROUGH, VERY SHALLOW, VERY WET OR VERY DRY	B LOW AVAILABLE MOISTURE CAPACITY is dominant hazard	Mangrove swamps	366A0
			Not recorded in Puerto Rico	

TABLE IX

SUITABILITY	LAND CAPABILITY CLASS	LAND CAPABILITY SUB-CLASS LIMITATIONS OR HAZARDS	EXAMPLES OF LAND CAPABILITY UNITS IN PUERTO RICO
LANDS NOT SUITABLE FOR CULTIVATION	VIII LANDS WITH LIMITATIONS THAT MAKE IT UNFIT FOR CULTIVATION, GRAZING OR FORESTRY, BUT MAY BE UTILISED FOR WILDLIFE OR RECREATION, OR TREATED FOR WATERSHED PROTECTION	NONE	Rock outcrop
			Deep, V-type (caving) gullies
			Barren land
			Deep, very light textured soil covered by water most of year
			Narrow strip of beach sand bordering the coast line and affected by the waves

TABLE X

USE OF LAND ACCORDING TO CAPABILITIES

LAND CAPABILITY CLASS		INCREASED INTENSITY OF USE								
		WILD LIFE	FORESTRY	LIMITED GRAZING	MODERATE GRAZING	INTENSIVE GRAZING	LIMITED CULTIVATION	MODERATE CULTIVATION	INTENSIVE CULTIVATION	VERY INTENSIVE CULTIVATION
INCREASED LIMITATIONS AND HAZARDS	DECREASED ADAPTABILITY AND FREEDOM OF CHOICE OF USES	I								
		II								
		III								
		IV								
		V								
		VI								
		VII								
		VIII								

LAND CAPABILITY CLASSES AS A FACTOR IN DETERMINING LAND USE IN PUERTO RICO

## 7. Principles and procedure of Farm Planning

By Dr. Joaquin F. Marrero

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### I. Farm planning is based on four important factors:

1. The land capability survey of the farm - proper land use.
2. The right combination of soil conservation practices - single practices are seldom effective in erosion control.
3. Maintenance and improvement of soil productivity.
4. Economically sound conservation farming.

All these considerations are necessary if we are to have a permanent and profitable use of the land.

### II. Some of the more important facts that must be considered in planning a farm are:

1. Type of farm to be planned (livestock, farm crops).
2. Feeding requirements for the persons and animals on the farm.
3. Cropping programme and rotation system of crops.
4. Farm equipment available on the farm.
5. Conservation practices to be established.
6. Other agronomic practices needed - liming, fertilising, etc.
7. Must always consider economic factors - is farmer making a profit?

III. The land capability map is the base map of the farm. By examining this map, one may obtain a great deal of information about the present conditions of the farm, such as: 1. Different classes of land in the farm; 2. The use the farmer is making of the land; 3. Acreage devoted to cultivated crops, pastures, woods, etc.; 4. Location of roads, lanes, streams, natural waterways.

IV. In order to get the work on a sound basis, and considering the limited technical personnel available, stress is placed on planning groups or communities of farms rather than individual scattered farms. Assistance can thus be obtained from farm leaders. These may be community, neighbourhood or family leaders.

V. An effective, well organised educational programme on soil and water conservation is a prerequisite to a successful farm planning programme. Some of the most important methods that may be used are: 1. Conferences, lectures, discussions with group of farmers by district supervisors, Extension Service, Forest Service, Vocational Agriculture, and other interested agencies. Also meetings of civic clubs, churches, bankers, schools; 2. Radio and newspaper programmes; 3. Motion pictures and film slides, exhibitions; 4. Contests, awards of prizes to winning farmers; 5. Field trips to farms having an established soil and water

conservation programme. Most effective results obtained when the farm owner himself talks to the other farmers about the benefits derived from a complete soil and water conservation programme.

- VI. It is highly important that the farm plan be thoroughly understood by the farmer, and that he is convinced of the benefits to be derived as a result of carrying it out.
- VII. It must be recognised that a complete farm plan is a long-range programme and will require several years to get it applied. It is designed to put the farm on an economically sound basis by improving the soil as well as the quantity and quality of the crops grown.
- VIII. There is no ready-made farm plan that can be used for all farms. Each farm differs in many ways from every other farm. The farm plan of one farm will not fit any other farm.

## B. SOIL PROBLEMS OF THE CARIB

### 8. The Present State of Soil Knowledge Caribbean Region

By Prof. F. Hardy

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The British Caribbean Region comprises (1) the following territories:

- (A) MAINLAND: (1) British Guiana, (2) Trinidad and Tobago, (3) District of Barbados, (5) British Honduras.
- (B) GREATER ANTILLES: (6) Antigua, (7) Jamaica, (8) Barbados, (9) St. Vincent and the Grenadines, (10) St. Lucia, (11) St. Kitts and Nevis, (12) St. Eustace and Nevis.
- (C) VOLCANIC ARC: (9) Windward and Leeward Islands.
- (D) CORAL ISLANDS: (10) Barbados (in part), (11) Bermuda, (12) Turks and Caicos, (13) Bermudas.

Soil-forming factors and, therefore, the derived soils vary in these territories.

#### (1) BRITISH GUIANA

The main divisions are: (i) the Frontlands of Amazonian origin; (ii) the Hinterland, a peneplain complex of Precambrian metamorphic and massive intrusions forming dykes that have produced rapid rivers and have thus prevented the colonisation of the Roraima Plateau, made of Precambrian sandstone, an escarpment, some 900 feet high, over which several rivers flow (e.g. Kaieteur). The climate is very wet and the dense forests.

The Frontlands soils are solotized solent soils of sugar cane when treated suitably with fertiliser are very old, ranging from infertile white quartz soils containing abundant ferruginous concretions which when dried out or eroded (for example, when the for giving rise to ironstone gravel and ironstone pavement) having restricted agricultural value. Not all Frontland soils, except that they are mostly quartz soils of basic rock covered with red earth. Many countries of British Guiana have counterparts in West Africa as outlined in Wegener's hypothesis which postulates that North America were once joined.

(2) TRINIDAD

This comprises a northern range of mountains, made of Jurassic and Cretaceous metamorphic rocks (schists and limestones), continuous with the mountains of Venezuela of which Trinidad and Tobago really form a part.- There is a small intrusion of andesitic igneous rock in the north-east corner. The rest of Trinidad consists mainly of Miocene-Oligocene sedimentary rocks representing the whole range from sandstones to siltstones, clays and shales to limestones and marls. The rainfall is high in the east and lower in the west. Most of the island was originally covered with forest. The topography is mainly lowlying.

The soils of Trinidad are relatively immature because the whole area, except the mountains, until recent geological times, was protected by a covering of Pleistocene Llanos deposits, once continuous with those of Venezuela. Hence the rocks have not long been exposed to the action of soil-forming agencies. Most of the soil-types are hydromorphic (Ground Water Podzol; Wiesenboden, Planosol); some are calcimorphic (Rendzina), and a few are Red and Yellow Podzolic or even "Lateritic", though not fully developed. Cacao, sugar cane, coconut, citrus and coffee are the chief crops.

(3) TOBAGO

This resembles Trinidad, except that igneous rock (diorite) is more abundant and comprises about one-half of the island. The soil developed over diorite resembles the Mucara soil of Puerto Rico. The rest is schist and sedimentary rocks, mostly limestone, the latter forming a large promontory in the West. Cacao, coconuts and peasants' provisions are the main crops.

(4) BARBADOS (Scotland District)

The rocks of the exposed north-east part of Barbados, not covered by coral limestone, resemble some of those of Trinidad and Tobago.

(5) BRITISH HONDURAS

This may be described as a central high peneplain of Carboniferous rocks, mostly igneous (grandiorite) and metamorphic (slate), surrounded by Oligocene limestone, covering one-third of the area, and continuous with the limestones of Yucatan. A large part of the territory is occupied by old coastal alluvium and newer alluvium of the river flats and banks. The area is mostly covered with magnificent rain forest, whose products (mahogany and chicle) comprise the main exports. Plans are afoot for the agricultural development of the territory.



### (6) ANTIGUA

Though small, this island presents complicated geology which may furnish the key to the geology of the Caribbean. There are old volcanic rocks in the south-west, limestones in the north-east, and volcanic tuffs and limestones in the central plain. Sugar cane is the chief crop, but yields depend on rainfall which is often sparse and not much above 40 inches a year. The soils are Chestnut Earth, Vlei (a hydromorphic type), and Rendzina (a calcimorphic type, derived from soft limestones and lagoon marl).

### (7) JAMAICA

This relatively large island bears a closer resemblance to Puerto Rico than any of the British Caribbean islands. It consists of a basement of cretaceous igneous and metamorphic rocks associated with younger rocks, namely, tuffs, conglomerates and limestones of Eocene age, which compose the Blue Mountains of altitude 7,000 ft. These are surrounded by an apron of Oligocene limestones, forming a level plateau, 3,000 feet high. The coastal flats on the south comprise Pleistocene to Recent marine and estuarial alluvia, and the interior basins, resulting from the caving-in on a grand scale of much of the plateau through the dissolution of the limestone, are covered with red residuary deposits exposed to waterlogging in the wet season.

The climate of Jamaica is variable, depending on altitude, as in Puerto Rico. Rainfalls as low as 30 inches occur on the southern coastal plain, and rainfalls well above 100 ins. occur in the mountains. Over most of the plateau, the annual rainfall lies between 55 and 95 ins.

Originally, Jamaica was covered by forests, but the need of fuel by the early sugar manufacturers brought about their complete destruction over most of the area.

The soils of Jamaica cover a wide range of types, many of which doubtless could be matched among the soil series identified in Puerto Rico. Thus, humid zonal groups, such as Red, Yellow and Brown Lateritic and Podzolic, occur in the mountains, where red soils, resembling the Catalina Series, are widespread, and on the dry coastal flats soils resembling Chestnut Earth occur. Intrazonal hydromorphic soils, such as Ground Water Podzols, occur in the interior valleys, and calcimorphic types cover the soft impure limestones and marls. The most ubiquitous soils in Jamaica, however, are the Terra Rossa soils, developed over plateau limestones. These closely resemble the hard limestone soils of Puerto Rico, for example, Tanamá, Bayamon, Matanzas, Almirante and Coto. In Jamaica, the parent material of a yellow soil resembling Coto clay provides bauxite, which is being commercially exploited.

### (8) BRITISH VIRGIN ISLANDS

Little is known about the soils of this area, though, doubtless,

they resemble those of the Virgin Islands of the United States, which have been investigated and mapped in some detail by officers of the U.S. Department of Agriculture.

(9) WINDWARD AND LEEWARD ISLANDS (Volcanic Islands)

These comprise (a) Grenada, the Grenadines, St. Vincent, St. Lucia and Dominica, and (b) Montserrat, St. Kitts and Nevis, respectively. They form an arc, some 400 miles long, stretching from near Trinidad in the south to near the Virgin Islands in the north. Martinique and Guadeloupe occur among the first group, and Saba, St. Eustatius, and St. Martin, belonging either to the French or the Netherlands West Indies, to the second.

The average size of a typical British volcanic island is about 180 square miles, with average population of 300 per square mile, or 2 persons per arable acre of land. The average height would be about 3,600 ft. Only some 36 per cent of the total area is cultivable, on the average, and another 36 per cent is permanently under forest, leaving 28 per cent as marginal land. The rainfall is concentrically zoned around the central mountain ridges, and varies from about 150 ins. to 35 ins. over the narrow coastal strips. The climate of the highlands is continuously wet or moist, with all months having rainfall over 4 ins., but that of the low grounds shows a weak, marked or intense dry season having one to 3 to 6 dry months with less than 2.4 ins. of rain. (Mohr's scheme.)

The volcanic islands were once clothed with forest, classed by J.S. Beard as Montane Forest over most of the highest ground having annual rainfall above 70 ins., and Seasonal Forest (Evergreen, Semi-Evergreen and Deciduous) occupying the land under rainfall between 70 and 50 ins. The vegetation of the dry coastal lands is mainly cactus scrub, and the coastal swamps are occupied by mangrove. The different kinds of vegetation, like the climatic elements, are arranged concentrically around the central ridges.

The geological structure of the volcanic islands is extremely variable. All are built up of a series of Pleistocene to Recent volcanic cones resting on an eroded and peneplanated basement of ancient volcanic rocks that were erupted in Miocene times (13 million years ago) from volcanoes arising from still more ancient (cretaceous) earth-folds. The "old residuals" are nowadays exposed around the periphery of several of the islands, for example, Grenada, St. Lucia and Nevis, but mostly they are covered over by the newer volcanic ejecta. The kind of volcano represented by the Pleistocene cones is the "explosive" type, in which lava flows are scarce and the main eruptive rocks comprise fragmental materials ranging in size from large boulders to fine dust. The kinds of rock of which the volcanic materials are composed are mainly andesite and basalt. These are

mostly devoid of quartz, though quartz-bearing varieties occur in a few of the islands, notably St. Lucia.

The points of origin and the sequence of eruption of the several volcanoes that make up each of the islands have fluctuated greatly, so that complex geomorphological land-forms have resulted. The following stages can be traced: (a) Old forms - (i) old residuals, (ii) very old cones, whose central plugs remain to form "pitons" or low sharp peaks, (iii) old cones whose sides are deeply dissected by erosion, and (iv) old glacis or gentle slopes comprising finer materials laid down by "black clouds" (mixtures of steam and hot dust) or washed down by water action, and afterwards eroded into deep wide valleys and sharp longitudinal ridges; (b) New forms - (i) young cones, having easily-recognised craters, (ii) eruptive cones, not yet extinct (for example, Soufrière Mt. in St. Vincent and Mt. Pelée in Martinique which erupted violently in 1902-3), and (iii) young glacis subtending young cones not yet dissected by water action. These, together with estuarial and riverine flats and raised beaches, present a wide variety of topography which has greatly influenced soil formation.

Thus, in the steep wet uplands where drainage is free, zonal soils, provisionally termed "Red Earth", abound over the old geomorphological volcanic forms, although they have not yet had time to develop over the most recent cones and glacis, whose soils have therefore been classed as azonal and provisionally termed "Fresh Ash" or Lithosol. Between these extreme kinds of soil, several less mature (intrazonal) kinds have been identified, whose present features appear to have been mainly decided by the prevalence of lime, liberated by the decomposition of the basic feldspars (calcimorphic soils) in the one case, or by the dominance of ground-water (hydromorphic soils) in the other. To the first of these classes belong "Brown Earth", derived from the coarser ejecta (boulders and stones) and "Yellow Earth", derived from the fine-grained materials (ash and dust). The component boulders of Brown Earth are weathered in onion-skin manner and more-or-less completely softened and decomposed to the core, forming a soft mass which may easily be cut, producing sections showing kaleidoscopic colorations. The topsoil is bright red-brown in colour and rich in exchangeable calcium, so that its reaction is usually alkaline. It is very fertile, and grows good crops of vegetables and cotton. The particles of volcanic ash comprising Yellow Earth are similarly well-weathered, the feldspar grains forming pseudomorphs composed of a kaolinite-like clay mineral, and the ferromagnesian grains giving rise to limonitic residues which colour the parent material bright ochre yellow. The topsoil is nearly black, and its reaction is slightly acid, though its lime status is high. In some respects, it resembles Rendzina, and its features appear to be similar to those of "Ando" soil of Japan.

The hydromorphic soils have been formed by the gradual sealing-up of the subsoil by the development in situ of colloidal clay minerals,

possibly augmented by the downward movement and accumulation of silica or hydrated iron oxide, which impeded the drainage. The first stage has provisionally been named "Terras", after the local name given to its parent material ("trass") which is used as road metal. The second stage has been called "shoal", because it gives rise to a hard pavement ("shoal rock") when eroded and dried out. Both stages contain new clay minerals somewhat resembling beidellite, which makes them plastic and sticky when wet and hard, and compact when dry. They are difficult to cultivate, and can support crops (such as cotton and sugar cane) only in the wet season. These two hydromorphic soils, developed over fragmental volcanic rocks, might be classed as Planosol.

(10) BARBADOS

The coralline part of this island is covered by a red soil (Terra Rossa) over the higher terraces, and by a black soil (Rendzina) over the lowlands. Intermediate stages occupy the terraced land between. The development of these two soil types may be explained in terms of the differing porosity of the underlying rock, and the proportional amount and nature of the included impurities, which may comprise either volcanic ash ejected by the volcanoes of the neighbouring islands, such as St. Vincent, or weathered materials derived from sedimentary rocks that make up the core of Barbados. The climate is wet in the upper lands between 100 and 200 feet, and dry near the coastline. The island was once covered by seasonal rain forests, but it is now entirely given over to the cultivation of sugar cane.

(11) BARBUDA

This coral island situated near Antigua is low-lying and dry, and its soils resemble those of Barbados. It is almost uncultivated, and is covered with thin deciduous forest and cactus scrub.

(12) BAHAMAS

(13) BERMUDA

The numerous coral islands comprising these two groups resemble the coral islands described above, in that their soils are either red or black, depending on the nature of the parent calcareous rocks, with regard to under-drainage and purity.

## 9. The Clay Minerals of British West Indian Soil

By G. Rodrigues

Up to the present time the clay fractions of only some of the major soil types occurring in the region have been examined, namely:

- (1) Talparo Clay of Trinidad
- (2) The Coral Soils of Barbados
- (3) Some Volcanic rock soils of the Lesser Antilles, e.g.
  - (i) Red earth derived from massive Augite-andesite,
  - (ii) Yellow earth derived from uniformly granular volcanic ash,
  - (iii) "Shoal" Soil developed over cemented ash and agglomerate.

The methods used have been chiefly chemical analysis including base exchange measurements, supplemented by examination with the microscope, dehydration curves and dye absorption. In one case only, the Talparo clay, we had the cooperation of Dr. Ralph Grim of Illinois, who examined the samples by X-ray diffraction and differential heating methods.

(1) Talparo Clay is an acid red clay derived from a sedimentary foraminiferal clay or shale of Oligocene age. Samples were obtained every 5 feet to a depth of 75 feet from cores taken by oil geologists. Evidence of weathering and of the ordinary processes of soil development were obvious to a depth of 40 feet. Briefly stated, the parent material below 40 feet had the following mineralogical composition: Kaolin, 40 per cent; Quartz, 20 per cent; Illite, 20 per cent; and a Chlorite, 15%. The soil consisted of Kaolin, 36%; Quartz, 38%; and illite, 23%; with little or no Chlorite left. The illite in both cases contains between 5 and 6 per cent of  $K_2O$ , and seems to have undergone little breakdown in soil formation. The reaction (pH) of the soil to 10 feet was 4.6, at 20 feet 6.4, while that of the parent clay was about 8.0. The base exchange capacity of the soil was 34 m.e.%, while that of the parent was 24 m.e.%. Exchangeable calcium was 8.0 and 1.5 m.e.% in parent rock and soil, respectively, and magnesium 15.0 and 13.5 m.e.%. In the process of soil formation, involving intensive leaching, the exchangeable calcium is nearly completely lost, but the magnesium maintains its high value.

(2) The Barbados coral soils were sampled on a traverse of the succeeding terraces, starting from the lowest at a height of 35 feet above sea level, the next at 135 feet, the third at 195 feet, the fourth at 422 feet, and the highest at 614 feet. The soil at lowest level is a black clay, while the one at highest level is a red clay, with the second and third being described as intermediate black, and the fourth as intermediate red. The five samples constituted a graded series, and the clay fraction showed a progressive change in the silica-alumina ratio from 3.2 in the black soil to 2.3 in the red. The base exchange capacity decreased (linearly) from 44 m.e. to

24 m.e.%. Dehydration curves were identical in shape in all the five samples, but the "adsorbed" water (lost up to 200°C) decreased from the black to the red, while the "crystal-lattice" water increased over the same range. The clays most probably consist mainly of a mixture of two minerals varying in proportion as we pass from one end of the series to the other. One clay mineral with a low base exchange capacity is most likely kaolinitic, while the other is possibly a beidellite, with high base exchange capacity and a fair amount of combined iron. On this latter assumption, the clay of the black soil would contain about 70 per cent of beidellite and 23 per cent of kaolinitic mineral, while the clay of the red soil would be just about the reverse in contents of these two minerals. Computing the composition of the beidellite component of the clay on Nagelschmidt's system to the basis of  $\text{Al}_2\text{Si}_4\text{O}_{11}$  produced an interesting graded series in which the iron replacement seems to increase as we pass from the black to the red clays. The soils apparently constitute a Catenary Association, which might, however, have been influenced by the nature of the parent coral and its impurities, and even by the igneous minerals from ash showers originating in the volcanoes of the neighbouring islands.

(3) The soils derived from volcanic rocks have been described by F. Hardy, in a paper submitted to the Conference; the following three main types have been so far examined:

- (i) The Red Earth derived from Augite-andesite is very much like the Cataline clay of Puerto Rico. The direct product of the primary weathering of the rock contains a high percentage of free alumina, most probably in the form of gibbsite. The clay of the final soil is composed of a kaolinitic mineral with a relatively high base exchange capacity (20 m.e.%) and a dehydration curve of the type of that of halloysite. The coarser fractions also consist (apart from unweathered minerals) of kaolinitic aggregates which resist dispersion.
- (ii) The Yellow Earth in its formation seems to follow a pattern similar to that of the red earth, in so far as the final products tend to be kaolinitic in composition but much more immature. The iron oxide is apparently highly hydrated, while the clay mineral seems to be more a mixture of highly hydrated silica and alumina in the proportion approaching that of kaolinite but not showing the characteristic dehydration curve of this mineral, in the examples so far studied. The mineral has been described as "allophanoid" for this reason. In the ashy horizons of this soil profile, where mechanical analysis reveals as much as 80 to 90% sand, the water absorbing capacity may be extremely high. This is due to the feldspar "pseudomorphs", which have retained the form of the original crystal, but which have been highly weathered and, in some cases, have completely lost their bases and a large amount of their silica content. This "pseudo sand", be-

sides having high water-absorbing capacity, also shows high base exchange properties.

- (iii) In the case of the "Shoal Soil", the weathering follows a different pattern. This soil is developed under impeded drainage conditions, and the clay component is decidedly more siliceous; its molecular silica-alumina ratio approaches or is well over 3.0. The clay mineral is variable, but seems to be one of the montmorillonite or beidellite class. Here again the coarse fractions (sand and silt) may also exhibit high base exchange properties of the same order as those of the clay component (200 m.c.). The main exchange base in the clay fraction often is magnesium.

These results have been obtained by what must be considered as quite inadequate methods, and must remain conjectural until better facilities for more refined analysis by modern methods are available.

## 10. Soils Problems of Surinam

By J.M. Verhoog

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After a brief description of the climate, geology and physiography of Surinam, special attention was paid to the soils problems in the coastal lowlands.

The soils in the coastal lowlands, which range in texture from very heavy clays to sands, are low-lying (slightly above to slightly below sea-level), and, therefore, are affected by a high groundwater table in the rainy seasons; they become even partly flooded.

The productivity of the land is limited by this unfavourable condition. Accordingly, drainage is a main problem in Surinam. It has been calculated that, for crops such as soybeans, corn, etc., on the heavy clay soils, the capacity of the drainage system should be as high as 70 mm. (2.8 inches) in 24 hours. Even then artificial drainage by means of mole drainage may be a necessary supplement. Experiments with mole drainage are in progress.

To collect information on the existing soil types, a detailed soil survey has been started of an area of about 3,000 ha. (7,500 acres) on a scale of 1:10,000. In connection with this survey, information is being gathered on the natural drainage system, land tenure, land use and farm management, to obtain sufficient data for land improvement.

Surinam is in urgent need of a land improvement programme with a view to land improvement of areas now under cultivation and the setting up of new settlements according to soils pattern, topography, etc.



## 11. Soil Survey of Puerto Rico

By Ray C. Roberts

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Puerto Rico, like many of the British Caribbean Islands Professor Hardy so vividly described last night, is also a good place to study the effects of the five commonly recognised genetic soil factors: namely, climate, parent rock, time, living organisms and relief - including man's activity. Soils everywhere are the products of the combined effects of these factors; no one factor operates alone. If the total effect of all the factors is the same in two sites, even though they are many thousands of miles apart, the soils will be the same and should be classified in the same soil series. If the soils are the same, knowledge regarding use, management, and yields from soils in one area should be very helpful in the other.

Owing to the wide ranges in precipitation, parent rock, relief, vegetation, age and drainage, many soil types occur in Puerto Rico. Examination of the soil map of Puerto Rico will show 115 soil series (including 352 soil types and phases).

I am very glad that I had occasion to work on the soil survey of Puerto Rico, which was started in 1928 and completed in 1935. I welcomed the opportunity to return again and again during that period. The work season was from about January to June. When the wet season started, the Federal men would return to the United States for summer assignments. In many respects this break in the survey was highly desirable, because it gave us an opportunity to reflect about soil problems that baffled us in the winter, and thus see them in another light when we returned the next fall. At times it was evident that we had not understood all that we saw. To illustrate this point, I mention an incident that happened in 1925 when I was working on the Nebraska soil survey during summer vacation in my junior year. At that time I thought I knew quite a bit about soils, at least I was digging many holes and taking many notes. During the course of the survey, Dr. C.F. Marbut visited the area. It was not long before he showed me many characteristics of the soil profile that I had never seen before, although I had been looking at them all the time. This example applies to most inexperienced soil surveyors. Furthermore, most of us see what we are trained to see - and very little more. More experienced men must help those with less experience to recognise significant features of the profile and landscape. After these features have been recognised, it is easy for men to see them the next time they are encountered. One of the requirements of a good soil surveyor is to keep his eyes open and to be on the alert to see everything he can in the soil profile, landscape, and the use of the land, and to recognise those things that will help him make a more useful map and report.

Mr. A.T. Sweet started the detailed soil survey in Puerto Rico in 1928. He was assisted by Mr. F.A. Villamil of the Insular Experiment Station. They worked in the area near San Juan. The next year Mr. James Thorp

Mr. Robert Wildermath, and I continued with the survey. We were assisted by Mr. Rafael Bird, Mr. G.A. Torruella, and Mr. Octavio Reyes of the Insular Experiment Station. One party worked near Ponce, another near Fajardo, and one near Isabela. In all three areas sugar centrals contributed part of the funds, so we knew that the soil surveys would be put to practical use just as soon as they were completed. We knew that the soil type boundary lines should be as accurate as we could make them; Thus the maps could be used in making sound recommendations for land use of specific tracts and as a basis for predictions on yields and soil-plant relationships.

A number of men in addition to those of the first parties worked at various times on the soil survey from 1930 to 1935. These included the following: S.R. Bacon, T.E. Beesley, W.H. Buckhaman, Z.C. Foster, Ralph Leighty, M.B. Marco, C.C. Nikiforoff, O.C. Rogers, A.E. Shearin, L.R. Smith, and M.M. Striker from the United States; and V.M. Alexandrino, Juan Juarez, Jorge Landron, Ferdinand Mendez, D.A. Rodriguez, Alfonso Reboyras, and J.A. Zalduondo from Puerto Rico. All of the men who assisted on the survey were college graduates. They did all the work themselves, such as driving the cars, examining the soil profiles, digging pits, collecting data, and delineating areas on the maps. The area was inspected by Dr. Mark Baldwin, and both Dr. C.F. Marbut and Dr. Charles E. Kellogg visited the survey while it was in progress.

The rate of progress was quite variable in the different areas, but on the average a party of two covered approximately  $1\frac{1}{2}$  square miles a day. As an approximation, I would estimate that the cost of the survey, including publication, ranged between \$60.00 and \$80.00 a square mile. Exact cost data are not available.

The method used in making the detailed soil map of Puerto Rico was to traverse nearly all the area in a car or on foot at intervals of one quarter mile or less. The plane table method (described in the Soil Survey Manual of 1937) was used during the first two winters and the last one. In 1931 the United States Navy took aerial pictures of approximately half the island. These pictures were on a scale of 1:10,000 and were used to good advantage in the soil survey. Some of the aerial pictures were made into mosaics and reduced to a scale of about 1:40,000. These were used in the field by covering them with thin pyralin paper upon which the natural and cultural features were drawn. The method most generally used was one in which the location of the soil boundaries, streams, houses, and other features was sketched on pyralin or kodaloid-covered contact prints taken to the field. Later the pyralin or kodaloids were compiled, traced, reduced, and adjusted to a plane-table traverse of the main roads. No set procedure was established for examining the soils. They were examined in many places to depths

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1. The number of profiles examined ranged widely from area to area. In some places 5 or more sites were examined within  $\frac{1}{4}$  mile of traverse, whereas in other places only one boring was made within 1 mile of traverse.

ranging from 3 to 6 feet with a spade and auger, in order to observe the variations of the physical and some of the chemical properties of the different horizons of the profile. Dilute hydrochloric acid and pH indicators were carried by the field men, and numerous tests were made. Soil samples of the saline and alkali areas were collected, and were later analysed with the modified Wheatstone bridge in temporary laboratories during rainy weather.

The general features noted in examining the soil were topographic position, drainage, parent material, vegetation, apparent productivity, erosion, and crops produced. Careful observations were made of the colour, texture, structure, consistence and thickness of the several horizons of the soil. The relative content of organic matter, character and distribution of roots and cracks, depth to lime, pH values, and other characteristics were also noted. These characteristics are approximately the same as Dr. Marbut's ten characteristics, given in Dr. Roy W. Simonson's paper, "Lessons from the First Half Century of Soil Survey." I suggest that any of you contemplating the making of a soil survey read his paper very carefully. Even during the first years of the soil survey of Puerto Rico, no difficulty was experienced in using the system or the criteria set up by Dr. Marbut for differentiating series. Mapping the soils in Puerto Rico was not greatly different from mapping the soils in the United States - that is, the criteria used in one area were also applicable to the other. For a time we were somewhat frustrated in trying to name the textures of the soils high in permeable clay, like the Coto clay we examined near the Isabela Experiment Station. At first we thought this soil should be classified as loam, owing to the ease with which it could be handled in the field. However, we decided to use actual particle size distribution as our basis and classify it as a clay, letting the series name take care of the physical characteristics - that is, Coto clay would be a permeable clay (probably kaolinitic), in contrast to Moca clay, which is a very plastic sticky clay (probably montmorillonitic).

At the end of each season official soil samples were collected from typical sites of nearly all the soil types. These were collected by horizons, and one set was sent to the Soil Survey Division at Washington, and a duplicate set was sent to Rio Piedras to the Insular Experiment Station. Chemical and physical analyses were made on many of the samples.

If I were to suggest an ideal procedure for making a soil survey of the islands in the Caribbean, I would recommend that the following materials be assembled before work was started:

1. Good aerial pictures on a scale of approximately 1:10,000, with controlled mosaics at scales of approximately 1:20,000 or 1:40,000.
2. A good topographic map on a scale of approximately 1:40,000, made with the use of the aerial photographs.

3. A good geologic map, with special emphasis on surface geology.
4. A good vegetation type map.
5. Climatic data, such as precipitation and its distribution, evaporation, fog, relative humidity, wind velocity, length of day, amount of sunshine, temperature and its diurnal, monthly, and annual patterns, and similar data, for many parts of the area, especially if the climatic conditions are variable from place to place.
6. As much information as possible on the past history of land use.

With this information at hand, the soil survey party is far better prepared for its work. I prefer fairly large parties, but this must be governed by local conditions. In each party, I would like to have a geologist and an ecologist with some training in soil science, or one soil scientist well trained in geology and another in ecology. I am assuming that all the soils men will be well versed in agronomy. The better trained the surveyors are in soil chemistry and physics and in agricultural engineering, the better the survey should be.

The area should first be adequately studied by the party chief. He should also collect management and yield data on the various crops, grasses and trees, insofar as possible. These will have to come from results on experimental plots and through information from the experience of land operators. The collecting of this type of data should be continued throughout the progress of the survey. The soil mapping should be kept uniform throughout the area, and above all it should be adequately reviewed and carefully correlated with other similar areas as the survey proceeds. The correlation should be made by a man who has had considerable experience with similar soils and land use.

I would prefer to use the contact aerial pictures in the field and place directly on them soil boundaries, streams, roads, houses, etc., and then transfer this information to controlled mosaics or topographic maps, whichever seem to be the better.

The report should be prepared somewhat after the pattern used in the Soil Survey Report of Puerto Rico but with additional soil groupings, such as a grouping of soils into families and more technical groupings related to land use. One simple improvement could be made in the Puerto Rico soil survey report by listing the soils alphabetically, both in the body of the report and especially on the legend of the map. This is more evident to us now that we have had time to use the report for a while.

There are also a few "Don'ts" in soil survey work drawn from my own experience. They are as follows:

1. Don't have any more legends than are absolutely essential. This was one of our greatest errors in mapping the soils of Puerto Rico. When we first started the survey we believed that the areas, each approximately 150 to 200 square miles, would be published separately, similar to the practice of county reports in the United States. Therefore, each area had a separate legend. After it was decided to publish the survey of Puerto Rico as one area, it was necessary to combine these several legends into one for the published map. This caused untold grief in the preparation of the final map for publication. Undoubtedly, errors occur on the published map that can be traced to the many legends - for example, symbol 25 may have represented Coto clay in the Isabela area, whereas in the Fajardo area this symbol may have been used for Fajardo clay, and in the Ponce area for Coamo clay. It can be readily seen that errors could easily occur in the published map with this kind of procedure. Fortunately, or unfortunately, I was in Washington during the drafting of this map, and I was called upon many times each day to answer questions regarding the legends.
2. Don't use the screw (worm) type of auger for most areas if a better type of equipment can be obtained. The screw type auger works fairly well in very wet poorly drained sites, but the core, or post-hole, type of auger, described in Proceedings of the Soil Science Society of America, Vol. 1, 1936, pages 305-306, and now manufactured of light weight material, is far superior to the old screw type auger. In my opinion the screw auger, which has been used for the last 50 years, is a dangerous instrument. Sooner or later it may injure the field man's back, especially when used in claypan soils. The greatest danger occurs when considerable force must be applied, at which the auger breaks loose from the soil suddenly.
3. Don't attempt to recognize and show individual series in reconnaissance mapping. I think it is much better to map soil associations than to try to map and name series. In actual practice, this is what must be done. Series used as mapping units in reconnaissance surveys generally cause considerable grief when the same area is mapped in detail, or when those series are mapped in the detailed surveys of other areas. In many instances in the past, series used in old reconnaissance surveys have necessarily been dropped or their definitions changed materially when detailed surveys were undertaken. This is due to the fact that the mapping units in the reconnaissance survey actually were soil associations rather than series.
4. Don't confuse mapping units and classification units. They may or may not be identical. Soil types are primarily classification units, which may at times also be mapping units. On the other hand, phases are mapping units, subdivisions of soil types significant to soil use and management. Definitions of phases may need change from time to

time because of changes in agricultural methods, land use, or prices, whereas the soil type (classification unit) should be relatively permanent.

Several persons have asked me this question: "If you were remapping the soils of Puerto Rico, would you use the same system as you used before?" My answer was somewhat as follows: "I would not make many changes in classification units. As far as I can determine, I would not combine any soil series. I might make further subdivisions in some of the series that appear to be mapped rather widely. Any additional separations would probably be based on differences in profile that are caused mostly by differences in parent material. I would make many changes, chiefly additional separations, in phases based on characteristics such as depth of profile, convex or concave slopes, and direction and degree of slope, all features significant to land use and management."

Undoubtedly the classification of series into great soil groups as listed in the soil survey report of Puerto Rico will need revision. Possibly these groups should have been designated as tentative rather than final. We did the best we could in grouping the series into great soil groups, but I am sure that, with the further knowledge we now have, and with the assistance of other soil scientists in the Caribbean area, considerable improvement could be made in grouping these soils. The classification we used was not considered the final word when it was prepared; we recognised gaps in our knowledge and understanding.

I sincerely believe that the great soil groups have an important place in our classification, and that they should be more easily recognised than lower categories, such as the family and series. I believe some people have the wrong concept of great soil groups - that is, they think only in terms of the ideal when looking at a soil profile. If the profile does not fit their ideal concept of the great soil group, they may hesitate to classify it. The great soil groups should be "great" and must be inclusive. I have been on a number of field trips in which some member of the party examining a profile, such as that of a Chernozem, will object to identification of the profile with that great soil group. In reality, he is thinking only of the ideal profile rather than of the range of profiles which must exist in a great soil group.

All of us who took the field trip Friday, Saturday, and Sunday were impressed with the effects of the soil forming factors on the soil types we examined. For instance, the Nipe soil derived from serpentine seems to be very highly laterised and appears to be a Red Latosol. The Catalina soils derived from tuffaceous material are less permeable and probably less laterised than the Nipe soil, and would probably be classified as Reddish-Brown Latosols. The Coto and Bayamon soils, both derived from limestone, have quite contrasting profiles. The former is yellowish, and

the latter red. They are both about equally permeable and friable, and appear to belong to the same great soil group as the Catalina series. The Corozo soils, characterised by white quartz sands over an organic hardpan which rests on gray clays, are typical of the Ground-Water Podzols of tropical areas. The Coamo soils, derived from mixed old alluvial material on the more arid south coast, are typical of the heavy-textured Chernozem soils of the tropics.

I believe all of us were impressed by the sequence of the Descalabrado, Mucara and Catalina series. The Descalabrado series is a lithosolic, Reddish-Chestnut soil occurring on steep south-facing slopes in the vicinity of Rincon, where the precipitation ranges from about 55 to 65 inches. With increasing rainfall this soil gives way to the Mucara series, a lithosolic Reddish-Prairie soil or Brown Forest soil.<sup>2</sup> Where the rainfall is more effective, as it is on concave slopes and nearly level sites within areas of the Mucara soils, typical Catalina soils are found. With even greater precipitation but with similar slopes, the Mucara soils grade into the Catalina soils. Within the larger areas of Catalina soils, only the very steep slopes are occupied by the Mucara series. Where the precipitation exceeds 90 to 100 inches, even the steeper slopes are occupied by Catalina soils. This indicates that, with similar parent materials, but with increasingly effective precipitation, the soils change from Descalabrado to the Mucara to the Catalina series. In some areas the Mucara and Catalina soils may occur side by side with apparently the same effective soil climate. This suggests that, in these areas, there is some difference in the parent rock, either in degree of hardness or ease of weathering.

These observations illustrate a few of the interpretations that can be made from the soil survey of Puerto Rico. There are many others. I sincerely believe that soil surveys, such as the one made in Puerto Rico, include fundamental soil information which can be interpreted now for many uses. This information can also be re-interpreted from time to time, as the state of our knowledge of soils or as social and economic conditions change.

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2. It will require additional study to determine to which great soil group this soil belongs.

## 12. Comment on Puerto Rico Soils

By J.A. Bonnet

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The geology, climate, physiography and soils of Puerto Rico were discussed and illustrated with maps in the paper that I have submitted to this conference. The soil classification procedure followed in three land areas of Puerto Rico, to be irrigated, was also discussed in a second paper.

In the soil tours, you have travelled through most of the zonal, intrazonal and azonal soils described in the Soil Survey of Puerto Rico. In a supplement<sup>1</sup> to this survey it was reported that: "The soil series of the humid area of Puerto Rico are about 52 times more acid than the soil series of the arid area. The former contains about twice as much organic matter and about half the available phosphoric acid and lime. Both contain about the same total nitrogen and available potash."

In the paper<sup>2</sup> distributed tonight, you see that 71 per cent of the total area of Puerto Rico is occupied by hills and mountains, that about 28 per cent of its land is adapted to continuous cultivation and 65 per cent to pastures and forests, that about 46 per cent of its soils are clays, of which 19 per cent are lateritic. The percentage distribution of each of the international soil groups and their respective mean productivity rating are also reported.

Chemical data and pot studies<sup>3</sup>, using the sorghum plant as an index, have revealed that, in general, the soils of Puerto Rico are low in nitrogen and are well supplied with available potash, and that those in the humid region are also low in available phosphorus. With regard to nitrogen and potash, good correlations have been found with most crops in the field. Short growing crops have responded to phosphorus applications, but no response has been obtained with sugar cane. Studies with radioactive phosphorus are being planned to obtain more definite knowledge on the role of this element in tropical crops and soils.

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1. Bonnet, J.A., Chemical data of Puerto Rico Soils. Correlation of data for humid and arid areas. Field response of crops to available phosphorus and potash soils, Res. Bul. 1, Agric. Expt. Sta., Rio Piedras, P.R., Apr., 1941.
  2. Bonnet, J.A., "Broad classification of tropical soils in Puerto Rico by various practical systems", Commonwealth Bur. of Soil Sc. Tech. Com., 46, 1-4, 1949.
  3. Capo, B.G., "A modification of Mitscherlich's method for the determination of the nutrient contents of a soil", J. Agr. Univ. P.R., 22(2), 137-170, 1938.



Mineral studies<sup>4</sup> have also been a subject of interest. Research on foliar diagnosis is progressing at the Agricultural Experiment Station. This is a promising tool that will help in a better control of fertiliser practices for tropical crops. Multiple correlation studies done by us in the salty land at the Lajas Irrigation Project, in southwestern Puerto Rico, which you have seen in the tour, is another valuable tool for determining when the yield of the sugar cane crop is depressed by a known salt concentration in the soil.

The soils around the vicinity of the ashy shale area, where the Agricultural Experiment Station at Río Piedras is located, reveal an interesting pattern. Eight different soil series are found. The red-grey mottled subsoil of the Vega Alta series, derived from tertiary limestone, which you have seen in the tour, is also found here. A well dug in this region revealed the red mottled clay down to a depth of 18 feet, followed by silt and clay down to a depth of 33 feet lying over the ashy shale. There was no remnant of the limestone, and apparently the soil was derived from the shale. Tonight, Dr. Meyerhoff, well known geologist, explained to me that the clay and silt were weathered products of the tertiary limestone that overlaid the shale. The soil classification made was, therefore, correct.

In conclusion, I wish to show you a soft white mineral, brushite ( $\text{H Ca PO}_4 \cdot 2\text{H}_2\text{O}$ ), found by Mr. Clifford A. Kaye, Geologist, U.S. Geological Survey, lying between the hard limestone floor and the earthy brown ore, so-called guano, in Mona Island, located between Puerto Rico and the Dominican Republic.

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4. Bonnet, J.A. and Riera, A.R., "Tracing the mineral from the soil to the plant to the animal blood. Part I. Effect of lime on the mineral composition of the soil, of the grass, and on the crop," J. Agr. Univ. P.R., 30(3), 138-158, July, 1946.

13. The Constituent Minerals of Soils, their Determination  
and some Observations on their Occurrence in the Soils  
of Puerto Rico  
By C.D. Jeffries

The constituent minerals of soils are considered to be those of the feldspar, quartz, mica and clay mineral groups. The study of these minerals in soils is carried out by petrographic and X-ray methods on the sand silt and clay fraction from which the free iron oxides have been removed. The removal of free iron oxides facilitates greatly the separation of the various mineral components of the sand fractions, and results in ready identification by means of the petrographic microscope.

With the introduction of the Geiger counter X-ray spectrometer, the speed of identification of the constituent minerals in soil has been greatly increased. With recently developed techniques, a satisfactory diffraction pattern may be obtained, in about 35 minutes, which, when compared with patterns of known minerals for identification purposes, completes the analysis in a relatively short time. These determinations are carried out with equal facility on the sand, silt and clay fractions, and, as a result, a fairly complete picture of the mineral constituents of soils is readily obtained.

In 1943 soil samples of 42 of the principal soil series of Puerto Rico were obtained and prepared for mineral study. These samples were taken on a profile basis whenever possible. X-ray patterns were prepared recently, and are now being studied. Preliminary results show that the sand fractions in general consist of quartz alone, quartz with varying amounts of feldspar (principally plagioclase), feldspar alone, and, in some cases, kaolin. Comparisons of the distribution of feldspar through the profile have resulted in some interesting observations; in some cases the feldspar decreases with depth and quartz increases, in others quartz decreases and feldspar increases.

These distributions are of further interest when it was noted that different clay mineral distributions occurred with differences in the feldspar distribution in the profile. When the sand fractions were chiefly quartz, kaolin predominated. When feldspar weathered more rapidly than quartz, hydrous mica and some kaolin made up the clay mineral fraction. Under certain conditions hydrous mica was the only clay mineral. In the cases when quartz disappeared more rapidly from the profile than feldspar, kaolin and beidellite occurred, and in the few cases where the sand fraction was practically all feldspar, montmorillonite occurred. Total exchange capacity increases from kaolin, to hydrous mica, to beidellite, to montmorillonite.

When this study is completed, it is planned to undertake further detailed mineral studies on selected groups of soils of known mineral composition, as well as field and laboratory investigations.

## 14. Some Observations on the Weathering of Rocks in Puerto Rico

By Howard A. Meyerhoff

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Soil science has been developed chiefly through the study of soil-forming processes and their products in the temperate and subarctic latitudes of Europe and North America. One of the severest handicaps to progress in soil studies in tropical and subtropical environments has resulted from efforts to apply the knowledge acquired outside the Tropics to the phenomena that occur within them. In the remarks that follow an attempt will be made to stress differences and contrasts, without ignoring similarities and comparisons. Furthermore, attention will be limited to those aspects of the subject with which a geologist is most familiar: the weathering of rocks, the wash of weathered material, development of slopes, and topographic texture in relation to conservation and land use.

Puerto Rico consists of an old (Cretaceous) mountain core with flanking limestone coastal plains. The mountain core is composed predominantly of pyroclastic materials of andesitic composition, with rare interrelated flows and marine limestones and ashy shales, all folded and intruded by small masses of serpentine and andesitic dikes, and by younger and larger stocks of diorite, quartz diorite, and granite and granodiorite. The Tertiary coastal plains consist of rather localized basal shales of Oligocene age overlain by a moderately thick section of Oligocene-Miocene limestone, divisible into formations that yield distinct faunas and distinctive weathering and erosional characteristics. These Tertiary formations are broad and elevated in the west, but narrow eastward, disappearing (probably by a combination of overlap and submergence) in the vicinity of Loiza (viejo), just east of Río Piedras.

The island enjoys a humid climate, ranging from a small area of rain forest in the Luquillo Mountains to the subhumid districts between Isabela and Cape Borinquen in the northwest and the coastal foothills in the rain shadow of the Sierra de Cayey and Cordillera Central fronting the Caribbean. The mean annual range in temperature is a scant 10°, though the diurnal range may be as great as 30°. It follows that decompositional processes are prevalent over disintegration in the weathering of rocks and soils, but one must not overlook or underestimate the importance of mechanical wash that results from the frequent torrential rains.

In the temperate zone students of weathering and erosion have fixed ideas about relative rates of rock decay, and it is considered axiomatic that granites and related coarse-grained igneous rocks are resistant to weathering and erosion, as are conglomerates and sandstones; shales and limestones are non-resistant, though for different reasons. In Puerto Rico and other humid-tropical and sub-tropical lands, these axioms of the Temperate zones are misleading and worthless, and new standards of reference must

be developed. Probably the best rock type for use as a standard of reference is limestone, though there is marked variability in texture, impurity content, etc., among limestones. Nonetheless, it may be assumed that, under similar conditions of temperature and precipitation, pure crystalline or semi-crystalline limestones will dissolve at subequal rates regardless of location. The time in which solution will progress in Puerto Rico as compared with Virginia may be shorter, but solely because most of Puerto Rico has 50% more rainfall than Virginia, and there is no winter season to arrest solution. The solubility rate, however, is the same within an upper limit controlled by the saturation of groundwater for  $\text{CaH}_2(\text{CO}_3)_2$ .

Applying the conclusion that the solubility rate of limestone is subequal in all humid areas with essentially equal amounts of precipitation and comparable groundwater temperatures, we have a basis for establishing relative rates of weathering and erosion in different rock types. To anyone accustomed to temperate zone phenomena, the results are extraordinary to the point of being paradoxical. The folded Cretaceous limestones form resistant ridges that exhibit topographic prominence in their lithologic surroundings. Tuffs, tuffaceous sandstones, andesite porphyries, ashy shales, and most pyroclastic breccias weather and wash more rapidly and are reduced to lower topographic forms. Even the granitoid igneous rocks are reduced at greater speed, as the lowland east of Caguas and the depression along Rio Caonillas demonstrate with reference to surrounding volcanic materials rather than limestones. The only apparent exception - the large intrusive mass composing the Sierra de Cayey - is exceptional only in size and location: its huge dimensions and its divide location are both protective features that have kept the interior of this range high in elevation (3000' +).

It has not been determined whether the speed of chemical decomposition in the Cretaceous volcanic rocks of Puerto Rico is accelerated by the extensive hydrothermal alteration that these rocks have undergone. That is a possibility calling for further investigation. However that may be, decomposition proceeds with a rapidity that disconcerts the Northern experts and leaves them incredulous regarding many elementary phenomena. Weathering of the volcanic rocks yields clay or loam, depending on the presence of free quartz in the parent material. Residual clays and loams form so fast, even in areas of deep dissection, that wash, creep, slides and other gravity-controlled mass movements impart to the hill and mountain areas uniform slopes approximating the angle of repose ( $31^\circ - 35^\circ$ ) as an upper limit, regardless of vegetative cover. Heavy precipitation carves such areas into fine-textured topography, and the combination of fine texture and steep slopes makes the country bafflingly similar in appearance to the topography developed in arid to semi-arid regions in the temperate zone.

Regardless of precipitation, slopes as steep as those characteristic of interior Puerto Rico would be condemned for agricultural use anywhere in the United States, and soil conservationists from the mainland find it

difficult to readjust their thinking to the contrasted soil-forming processes active here. In the United States rocks decompose so slowly that slope wash on unprotected declivities outstrips rock decay, and fresh rock is quickly laid bare. In Puerto Rico this can happen, though more slowly, and only where a crop with low soil-protecting potential - e.g., tobacco - is raised on slopes approximating the angle of repose.

Too much protection, in fact, is fatal to fertility. I am indebted to Dr. Jeffries for figures that give statistical and quantitative point to my own qualitative observations. He informs me that soils containing feldspar have a productivity rating of 2.8(?), in contrast to those lacking feldspar and in which the productivity index is 6.3. The volcanic and igneous rocks, except the serpentines, all have high soda-lime feldspar contents, but the feldspar decomposes quickly. It follows that it is both beneficial and essential for slope erosion to proceed at a rate that will bring new feldsparic ingredients within the sphere of plant use. One noteworthy exception must be made: the diorites and other coarse-grained igneous rocks undergo initial decay along crystal boundaries, and the rock breaks down into a coarse sub-soil composed of the individual mineral grains - a process which I have named granulation. The products of granulation wash so readily that prolonged vegetation protection is required to promote mineral decay to the point of plant use. In such rocks all the standard methods of soil conservation in use on the mainland may be called for, but elsewhere fertility depends on controlled erosion and, in the lowlands, on periodic floods. To arrest these processes imperils the fertility of the land and the subsistence of the dense agricultural population that lives on the land.

Many other aspects of weathering invite discussion, and several of them have been dealt with briefly - and superficially - in the other paper I prepared for this conference. The high-iron laterites formed from the serpentine and the high-alumina laterites that are associated with certain Eocene limestones in the Dominican Republic, Haiti, and Jamaica raise many interesting questions regarding lateritisation and the weathering of limestones in general. Exhumed soils and some of the transported soils present special problems for consideration and further investigation. Obviously the subject of soil formation is ramified and complex, and I can merely hope that these geological notes and observations will throw some light, however, faint, on vital problems in soil science, land classification and soil conservation.

15. The Soils of the French West Indies and especially those of Martinique

By H. Stehlé

I. GENERAL INFORMATION: Position of French Islands very scattered; for example: Dominica (B.W.I.) lies between Guadeloupe and Martinique; St. Bartholomew near Puerto Rico. (Map of location and zones of the Archipelago distributed).

1. Martinique: South of the Antilles arc (Windward Islands).

2. Guadeloupe and Dependencies: North of Antilles arc (Leeward Islands).

Guadeloupe: two Islands: (Grande-Terre  
(Guadeloupe (stricto sensu)

Dependencies: (Marie-Galante  
(Désirade  
a) Nearby (Saintes  
(Petite-Terre

b) Distant (Saint Bartholomew  
(Saint Martin (half Dutch)

The political and administrative divisions based upon geography are not those necessarily considered by pedologists and ecologists.

II. SOIL FACTORS: The main soil factors in the French West Indies are:

1. Parent-rocks: Great diversity: labradorites, syenites and basaltic rocks in Guadeloupe; dacites, labradorites and andesites in Martinique; zoned labradoric rocks in Saintes; volcanic ash and dust deposits in the two largest islands (igneous formations).

Limestone: Miocene in Grande-Terre, Désirade, Marie-Galante; calcareous oligocene superior deposits in Martinique: north (Trinité) and south (Vauclin, Ste. Anne); (sedimentary formations).

Quaternary alluviums: Lamentin Coastal Plain in Martinique (fertile).  
Maps in coloured crayons showed.

2. Climatology: Map of climatic zones of Martinique from 1 m. of rainfall (Caravelle) to 8 m. high average (Mt. Pelée); 8 zones showed from coast to the centre of the island, greatly influenced by the main lines of relief, altitude and forest.

The principal factors of climate are:

- (a) Precipitations: Amount and distribution during the year (variations).
- (b) Atmospheric humidity: Complete saturation under trees in forest (100%); not in dry districts.
- (c) Temperature: Average around 24°C, but variations indicated in Caribbean Forester (Suppl. 1945-46).
- (d) Winds: Action on the soil. Erosive factor and upon evaporation for soil and plants.
- (e) Evaporation and Insolation: Diagrams showed. Maximum during February and March.

Necessity for studies of combined factors:

Aridity index of E. de Martonne (France:  $i = \frac{P+t}{10}$  (P = rainfall and t = temperature)

Xerophytic districts:  $25 < i < 50$

Cultivated lands:  $50 < i < 75$

Non arid zones:  $< i < 20$

St. Bartholomew Island: driest island of F.W.I.:  $i=27.7$

Hythergraphs and Climogrammes for dry and rainy parts are showed.

3. Natural Vegetation: Forests, pastures and cultivated lands. Distribution very intermixed. Main forest types (Map of Archipelago, July, 1944 and coloured maps drawn). Corresponding types of J.S. Beard (1949).
  - (1) Mangrove (swamp formation)
  - (2) Xerophytic forests (coastal woodland, evergreen bushland, deciduous seasonal forest and dry scrub woodlands)
  - (3) Mesophytic forests (calcareous and volcanic facies): semi-evergreen and evergreen seasonal woodlands.
  - (4) Hygrophytic forests: rain forests and lower montane rain forests, and
  - (5) Altitudinal forests (alluvial, volcanic and culminating facies): elfin woodland, montane thickets, palm brake.
4. Topography and Physiography: Plains, plateaux, mountains of various types and slopes are briefly discussed for Martinique and Guadeloupe.

The slope is the main factor for erosion action, and man adds another influence.

5. Microbiology: Example given: Ash of Mt. Pelée: Possibility of crop plants only after the establishment of microbiotic-flora, principally of nitrogenous bacteria.

III. PRESENT STATE OF PEDOLOGICAL KNOWLEDGE: See the paper presented at this Conference by H. & M. Stehlé: Four periods are sketched from Pre-Columbus Caribs to the present time.

Report by Blanche and Stehlé summarised in Caribbean Commission Monthly Information Bulletin, October, 1949, on regional programme of Soil Survey.

IV. APPLICATION OF SOIL SURVEY TO LAND UTILISATION: Map of present land use explained: sugar cane land, banana plantations, cocoa, coffee, pineapple crops, food plants and coconut trees along the coast land.

Generalities respecting the relationship between crops, soil and climate: pineapple at Trinité (Martinique) in acid soils, pH near 5.5 and 1 m. 80 rainfall, on lateritic clays similar to Catalina clays (Puerto Rico).

Sugar cane with 11 ratoons in certain fields of Lamentin plain of Martinique with alluvial soils of quaternary geological period.

Bananas on dacitic soils of Carbet Mt., pH=6, SiO<sub>2</sub>=60% and CaO=5% only. Dacitic soils are the most acid.

In general: time, physical state of the parent rocks, cohesion between stone elements, mass, pH (often  $4 < \text{pH} < 6.5$  in acid soils), with erosive agents. Disintegration factors are prevalent.

The action of man must be taken into consideration because the land has been under cultivation for more than three centuries. Tobacco, ginger, indigo and various spices were the first crops.

V. LAND IMPROVEMENT, CONSERVATION AND RENOVATION: More detailed maps on geology, climate, vegetation, topography, and aerial photographs showing land utilisation, etc., are necessary for Martinique and Guadeloupe. The preparation of these should be undertaken by specialists.

For general policy, Code Forestier of France must serve as basic principles for soil conservation, and is a good example for the whole of the West Indies.



- VI. CONCLUSION: We must follow the lesson of spontaneous vegetation that is: strength, harmony, equilibrium and continuous life. It is our duty to undertake systematic renovation of soils and protection against erosion, which turns the fertile lands into desert countries and takes to the sea the best of our national patrimony. We must conserve the soil in the Caribbean Territories for the future generations.

16. Report on the Action Taken by the Forest Service  
for the Conservation and Improvement of the Soils of  
Guadeloupe

By P. Moulin

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Every problem posed by erosion, conservation and rehabilitation of soils in tropical regions is connected with the ligneous formation. It is generally admitted that the formation and evolution of soil depends on the four following factors:

Climate  
Parent Rock  
Topography  
Vegetation

If two of these factors (Parent rock and Topography) are entirely imposed by nature, the other two (Climate and Vegetation) may be more or less modified by man.

Moreover, the influence of forested mountain masses on the local climate is recognised, and the part played by forest vegetation on the formation of humus and the decomposition of the rocks has been described at length.

Specialists in forestry have, therefore, a great responsibility in elaborating programmes for the protection and improvement of the soils. After having taken pedological control measures, they must indicate whether, in the particular cases studied, methods employed in forestry can produce satisfactory solutions which are likely to be in accordance with the technical propositions of other services and, furthermore, they must take into consideration the social and economic needs. When, however, a programme has been drawn up and approved, the business of implementing it still remains.

The limiting of the felling of forests and the reforestation of worn out lands, which are measures of the utmost importance, arouse the ill will of those who benefit from cultivations in forest clearings and of those who do not wish to, or cannot, advance the money necessary for forest reconstruction work.

Fortunately, the Forest Service has means of action. In order to protect the forests, forest guards may now make charges against persons for infringement of forest regulations. The number of these guards is now sufficient, and they are supported by a severe regulation of the French Forest Code in tracking down offenders. This regulation provides very heavy fines for unauthorised felling of trees in particular.

In Guadeloupe, it may be said that the Forest Inspectors have

practically put an end to careless cutting of timber, by defining the boundaries of State land, and by rigorously pursuing persons guilty of offences against the forest regulations.

On the other hand, the Forest Service which is greatly indebted to the comprehensive forest policy of the Prefect, M. Philipson, has at its disposal at present important credits from the general budget, the National Forest Funds, and the Funds for equipment of Overseas Departments. It has been able to undertake important improvements on State property and to assist private reforestation to a large extent, by taking charge of the work when the interested party so desired.

The Administration is at present studying requests for the reforestation of more than 5,000 hectares of impoverished lands with very superficial soil.

The Forest Service, however, is not systematically opposed to all felling of trees; it pays due regard to the needs of agriculture. Thus, lest the inhabitants of the poor forest villages on the leeward coast, who have not enough land for cultivation, should cut down the trees on the slopes where the conservation of the soil is dependent upon the presence of the forests, the Forest Service has established a project for clearing a part of the virgin forest on the plateau. This cleared land will be served by a forest route, and is intended to tempt the population to migrate thither.

The implementation of this project, which would provide against dangerous deforestation, would have the further advantage of establishing a specialised labour force which may be used for management and exploitation all along the most important forest route in the Department.

## 17. General Conditions in the Dominican Republic

By Miguel Cesteros

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The Dominican Republic, with an area of approximately 19,121 square miles, and a population of 2,151,000 inhabitants, occupies the eastern portion of the Island of Hispaniola, which is situated between Cuba and Puerto Rico.

Its sub-tropical climate makes it suitable for the production of various agricultural crops.

The Republic occupies about 82 million tareas (a tarea is a Dominican measure equivalent to 90' x 90'), of which 32 million are set aside for the development of agriculture and animal husbandry. Of these 32 million tareas, there are actually about 16 million which are under cultivation or used for pasturing animals, that is, about 20% of the total area of the country. The remainder of the land is situated in the five chains of mountains which are found there. It is covered with forests, approximately 12,000 tareas of which consist of pines native to the island and certain valuable timbers.

These mountains rise to heights exceeding 3,175 metres, the highest altitude in the West Indies. The highest peak has been named Trujillo Peak in honour of the President.

The topographic conditions of our country may be deduced from this short sketch, as also the susceptibility of our lands to erosion.

The heavy downpours of rain, the antiquated methods of cultivation, the ambitious exploitation of our timbers, the necessity of many of our farmers to settle on these lands in order to obtain their food, the big fires that frequently originate in our forests, etc., are important factors which have contributed to a rapidly increasing erosion which threatens our very means of existence.

Fortunately, the Government, inspired by sound principles for conserving the national soils, is taking the first steps towards reducing the effects of erosion and a Department of Soil Conservation is already established and is attached to the Department of Forestry and Agriculture.

This, however, does not mean that the problem has been solved in any way.

The lack of technical men qualified in this field reduces our efforts and makes it evident that the road ahead may be a long and hard one.

At present the Republic has two experts in soil conservation, who

qualified in the United States under the auspices of the Department of Agriculture of that country and we are earnestly endeavouring to instruct the 2 million inhabitants in the dangers of erosion.

Fortunately, assisted by the campaign of propaganda which is being carried on throughout the world, sponsored by the United States of America, we have succeeded in awakening in our people an awareness on the subject of erosion and its dangers. This is the first indispensable step towards combating erosion.

Our next step has been to begin instructing members of the staff employed by the Department of Agriculture, and to open various stations for demonstrating the methods of combating erosion and improving land use.

Nevertheless, as you all know, after making the aerial photograph of the soils, which is already very far advanced, the soils must be mapped and classified and, unfortunately, we have no technicians who are capable of carrying out this necessary task.

This is a problem with which other countries of the Caribbean are faced, and one of the most interesting points which I think this Conference should consider and endeavour to solve.

Perhaps it might be possible to arrive at a satisfactory agreement whereby all the countries bordering the Caribbean may be able to enjoy fully the technical cooperation of the countries which can assist in this way and even to obtain economic assistance; for you know, that there are many peoples in the Caribbean whose economy does not permit them to enjoy the necessary resources for those labours.

The struggle against erosion is a battle to save humanity from possible disappearance and, therefore, countries that possess the economic resources that are needed should not hesitate to extend their aid to countries which lack them, for in the end, the consequences of the fall of the weaker countries will rest on the shoulders of the survivors.

Therefore, I take the opportunity in this short statement, to make the following suggestions which I ask that you bear in mind in making your recommendations:

1. The establishment of an Institute in the Caribbean area whose essential task will be the directing and organising of propaganda for the purpose of awakening an awareness in all the inhabitants of the area, which will enable them to understand, in all senses of the word, the fatal consequences of erosion and the urgent necessity for everyone to join in combating it.

2. That this Institute be responsible for supervising, directing and guiding all work connected with the Conservation of Soils in the entire Caribbean area.
3. That experts qualified in all branches of the subject should work under the control of the Institute, so that their services may be available under a wide programme for international cooperation, to all the territories of the Caribbean that may require them.
4. That economic assistance be given to the countries that lack the necessary resources, so that they may not be left out in the great crusade against soil erosion.

It seems a utopian idea to think of the implementation of this project unless the concessions provided in President Truman's Point Four Programme are made available to us.

It is now the task of the Caribbean Commission to make the necessary approach to World Organisations which have been created for this purpose, in order that this project may be put into effect.

## 18. Soil Survey and Land Classification in Colombia

By José V. Lafaurie Acosta

Area covered by the survey approx. 2,500,000 acres.

### Types of survey:

- I. Zone with slopes from 0 - 10%, very detailed soil survey, area surveyed, about 500,000 acres.
- II. Zone with slope over 10%, not very detailed soil survey - area surveyed, about 2,000,000 acres.

### Base maps:

Aerophotographic. The job of the survey is translated to a very accurate geographic chart - Scale 1:50,000 and another 1:20,000.

### Detailed survey:

- (1) The aerophotograph is the base map.
- (2) We classified in the field the soil type: that is our unit of classification. The soil types are grouped in series, and these are classified in great soil groups. Each soil type is analysed chemically and physically.
- (3) Each type is classified according to:

Slope: 0-1%, 1-3%, 3-5%, 5-12%, 12-25%, over 25%.

Erosion: No erosion, slight erosion, medium erosion, severely eroded soil.

Stoniness: Stone on the surface, or in the profile, over 50%.

Lime: Each type of soil is tested with HCl acid.

Farm Boundaries: The boundary of each farm is surveyed, similarly the internal boundaries.

A report is prepared dealing with:

- (a) Geology and physiography of the Zone;
- (b) Climatology;
- (c) Description of the soil type;
- (d) Crops that are more successful in each soil type - and so forth.

We then make the land classification of the area surveyed and the map of land utilisation.



## 19. Soil and Agriculture Conditions in Guatemala

By C.S. Simmons

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Guatemala, the northernmost of the Central American Republics, includes the western end of what I believe is called the Antillean Cordillera by Schubert. It is, then, physiographically related to the islands of the Caribbean, and perhaps has many soil characteristics that are comparable to these areas. It includes about 48,000 square miles, approximately the area of the State of Tennessee or the Republic of Cuba. The Republic is irregular in shape. It lies immediately south of Mexico and north of Honduras and El Salvador. Guatemala City, the capital and largest city, is situated at 14° North latitude and 90°W. longitude. It is almost directly south of New Orleans, Louisiana.

Soil, climate and vegetation characteristics are probably as varied as any area of similar size in the world; elevation varies from sea level, at both sides, to over 14,000 feet at Volcano Tajumulco near the western border, and a sizable part is more than 7,000 feet above sea level. Perhaps the most outstanding physiographical feature is the line of volcanoes that roughly parallel the south coast about 20 miles inland. Rainfall ranges from more than 150 inches, at an elevation of about 3,000 feet on the Pacific slope, to less than 30 inches in parts of the East. Vegetation varies from dense, high rain forest, both on the Pacific slope and in the north, to scattered xerophytic shrubs, cactus, and grass in the dry parts, and includes alpine associations of fir and pine on the high mountains.

Temperatures are generally high, especially during the day, but in the higher areas frosts are common from October through February. Snow is practically unknown, as the cold season coincides with the dry season.

As far as I have been able to learn, no physiographic studies have been made; therefore, tentative divisions have been proposed. On the south is the Pacific Coastal Plain, a low, flat plain that averages about 12 miles wide. This extends from sea level to an elevation of about 500 feet, and has a uniform gradient of about 1 per cent. Between this and the line of volcanoes is the Pacific Piedmont - a region of coalescing alluvial fans. This has been divided into Lower and Upper subdivisions or sections. The Lower Pacific Piedmont section is about 6 miles wide, and extends to an elevation of about 1,500 feet. The gradient ranges from 7 per cent in the upper part to 2 or 3 per cent in the lower. The Upper Pacific Piedmont extends to the foot of the volcanic cones, a distance of about 4 miles, and has a maximum elevation of about 5,000 feet above sea level. The gradient ranges from 22 per cent at the base of the volcanoes to 7 per cent at the lower edge. Inland from this is the narrow band of volcanoes, some of which are still active. The central part of the Republic is a dissected Interior Plateau that will, when more data are in, be subdivided. It ranges in elevation from more than 7,000 feet in the west to about 3,000 feet above

sea level in the east. A prominent feature of this region is ash terraces, nearly level, flat-topped, remnants of ash plains. Many are relatively small, undissected valley floors or "bolson" valleys surrounded by mountainous land, but most are highly dissected remnants of old ash terraces. Some of these include several hundred square miles. The ash deposits are largely of pumice and, in many places, are several hundreds of feet thick. Dissection is in a young stage, consisting of sharp-lipped barancoes or gullies, many of which are more than 200 feet deep. North of this plateau is the Sierra Madre or Cuchumatanes Highland, the western end of the Antillean Cordillera mentioned above. This is a region of uplifted limestone that, in places, reaches an elevation of more than 10,000 feet, but in most places is about 5,000 feet above sea level. It is a rugged, broken region and has considerable karst. The Northernmost province is the Peten or Yucatan Lowland - a nearly flat limestone plain, part of the Yucatan Peninsula. This ranges in elevation from about 1,000 feet in the south to less than 500 in the north. There are other prominent features, such as the Sierra de las Minas in the Central-North Coast, about which I do not yet have sufficient information for classification. This is a region of old igneous and schist rocks.

The soils of the Pacific Coastal Plain appear, from studies made to date, to consist largely of light coloured clay soils on reddish-brown clay subsoils. They are neutral in reaction, plastic when wet, but fertile, and, with proper management and irrigation, should be highly productive of food, forage and fibre crops. The rainfall ranges from less than 40 inches near the coast to about 100 at the inner margin. It is principally used as pasture at present, with only a small portion improved. It is my opinion that this is the part of Guatemala that can be most easily and successfully exploited and improved. Included in this region are extensive areas, I do not yet know how extensive, of sandy loam to silt loam soils developing on sandy deposits. These are very dark brown to a depth of about 15 inches, have a high content of organic matter, are very friable and, when irrigated, productive. It is on this soil that the United Fruit Company have the successful banana plantation at Tiquisate.

The Lower Pacific Piedmont is characterised by deep, friable, dark coloured soils. The surface layers are dark-brown silt loams or clay loams to a depth of about 20 inches. The subsoil is distinguished only by a lighter colour; there is no appreciable texture change. The reaction is slightly acid to neutral. Rainfall ranges from about 100 inches at the lower part to 150 inches inland. This is the area where practically all of the cane is grown, but corn, rice and bananas are important crops, and some cacao and coffee are produced.

The Upper Pacific Piedmont is also characterised by deep, friable, dark-coloured soils. The surface layer in many places is a very dark brown silt loam that is more than 25 inches thick. These subsoils are yellowish-

brown silt loams or silty clay loams, but in most places there is little textural change from surface to subsoil. The apparent specific gravity is less than 1, and moisture holding capacity is high. Reaction is slightly acid to neutral. Rainfall in this region varies from 150 to more than 200 inches; the highest rainfall occurs at elevations of about 3,500 feet above sea level. Coffee is the principal crop. In many places this is interplanted with bananas that not only serve as shade trees but also bring in considerable revenue. Cinchona is also grown in the upper part of this region, but plantations are not, at present, being expanded.

The volcanic zones consist largely of unconsolidated volcanic ash. The slopes are steep, about 65 per cent, which appears to be the angle of repose for this material. It has been noted that the soils of the Pacific Piedmont have developed largely on pumaceous material, but the cones are almost entirely of dark coloured, perhaps matic, material. There appears to have been at least three stages of volcanism; an old, represented by Volcan Zunil; an intermediate, represented by V. Santa Maria and V. Agua; and a recent, represented by V. Fuego, not to mention Santiaguito, an active volcano. This last is not contributing material to the surrounding area at present. It was born in October 1902 at the base of V. Santa Maria, when this volcano exploded and buried more than one hundred square miles under ash, in many places to a depth of 10 feet. The area of volcanic cones is not cultivated, but a soil has developed to a depth of 20 cm. from the fresh ash that fell in 1902, and coffee is planted on this.

The soils of the Interior Plateau are extremely varied in character, depending on age and kind of material, rainfall, dissection and other factors. The important soils occur on the broad ash plains on gently undulating to nearly level relief. The surface soils, to a depth of about 10 inches, are dark brown clay loams. The subsoils are brown clays that grade at a depth between 4 and 8 feet into partially decayed pumice. This material is weakly cemented, road cuts are made with perpendicular sides, and there is no appreciable sluffing. These soils are fertile, potentially productive, but are at present, after perhaps 1000 years of continuous cropping with no management other than planting, hoeing and harvesting, in what I have called "equilibrium with starvation". The average yields are about 14 bushels of maize per acre, but accurate data are not available. Reports have been made that the yield trebled after two green manure crops were interred. Corn and wheat, continuous or in relation with each other, are the principal crops grown on the flatter areas, and corn in a shifting system of cultivation, "milpa", on the sloping lands - black beans, a staple food crop in Guatemala, are interplanted with corn.

The limestone soils of both the Sierra Madre and the Peten Lowland consist principally of Rendzinas, which need no description here, and of deep soils resting on limestone. The latter vary in characteristics, but a common soil is characterised by a very dark brown silt or clay loam surface

soil that is about one foot thick. The subsoil is reddish-brown clay that, with some sub-horizon differences, rests on limestones. Depth to solid rock varies from 3 to as much as 20 feet. The subsoil is extremely acid, as low as pH 4.5, and this is one of the few acid soils occurring in Guatemala. Corn, in shifting agriculture, is the principal crop in the western and highest part of this section. A large part, however, is isolated from communications and is not cultivated. The eastern part, in the region of Caban, is an important coffee growing region. The Peten, about one third of the area of the Republic, is sparsely inhabited. It is in a wild gathering economy; chicle and mahogany are the principal crops.

We are presently making a Reconnaissance Soil Survey of the entire Republic. This to serve as a basis for agricultural research and exploitation or development.

Over the greater part of Guatemala a system of shifting agriculture, locally called "milpa", is practised. With the exceptions of a few places where population pressure is heavy, this has been adequate to support the people and protect the soil. We are, in my opinion, on the threshold of a more intensive agriculture, and I fear that, with the use of machinery and fertiliser, not accompanied by the incorporation of organic matter, soil damage will result. We already have some reports that, after a few years use of commercial or "chemical" fertilisers, soils are becoming hard. This is especially dangerous in the sloping or hill lands, as I fear serious erosion must surely follow the depletion of these soils, should continuous cultivation be attempted. Our opportunity lies in developing a system of cultivation for these lands that will permit sustained production at a high level of productivity.

## A P P E N D I X C

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### PROGRAMME FOR FIELD TRIPS

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#### (a) Field Trip I

First Day: Friday, March 31, 1950

1. Travel along highway No. 1, an old historical highway first built by the Spaniards to connect San Juan, (230, 231)<sup>x</sup> and Ponce (119,087) in the south.
2. Left: Río Piedras (99,026), with Central San José, a sugar cane factory.
3. Right: A new concrete highway is being constructed. The exposed roadcuts reveal the red Fajardo clay (p. 273)<sup>xx</sup>.
4. The first bridge you cross is the "Los Frailes", one of the oldest Spanish bridges in the Island.
5. We are now leaving the terrace country and are entering the hill country with its brown shale soils. The shallower shale soils are called Múcara (p. 213-214); the deeper soil from the same parent material on more rolling topography is called Juncos (p. 214).
6. On the steep slopes of these hills sugar cane is grown. Where the sugar cane trash is used as a mulch, good erosion control is obtained. On slopes of 45 per cent or less, the soil loss is probably less than 1 ton per acre per year where trash is used as a mulch; the loss is more than 10 times this when the trash is burned, according to erosion plot data.
7. (Km. 26.4) on the right hand side of the road is a Torres clay (p. 267-68) profile exposed by road cut. This lateritic soil is derived from material washed from the Catalina, Cialitos, and associated red and purple lateritic soils of the humid upland sections.

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x Population - Estimated population of Puerto Rico as of July 1, 1948. Information taken from Annual Book of Statistics of Puerto Rico, Fiscal Year 1947-1948.

xx All page references are given for the Soil Survey of Puerto Rico by R.C. Roberts.

8. Many tobacco fields can now be noticed on either side of the road, in this area, many of them on rather steep slopes. The broad valley which we enter approaching Caguas is the Caguas valley, a large area of level land within the interior of the Island, at elevations between 60 and 100 metres above sea level. On the hills of the valley border, sugar cane is grown on slopes up to 60 or 70 per cent, except where the soil is too shallow.
9. The city of Caguas (62,439) is the largest within the interior and fourth largest city in Puerto Rico.
10. Left: As we leave Caguas, we see a new housing project where a large number of concrete houses is being completed.
11. Intimately associated with the shallow Múcara soils of this section is the Naranjito silty clay loam (p. 215). It is a reddish-brown soil derived from tuffaceous rock and more acid than the Múcara.
12. The steep slopes of these mountains are planted to tobacco, usually followed by corn or beans and then by volunteer grass.
13. (Km. 46.2) This road cut reveals deep, reddish upland clay soil derived from andesitic tuff and tuffaceous shale. Catalina clay is well represented here (p. 185-188).
14. This is an old tobacco area, but most of the tobacco has been replaced by sugar cane. The system of ditches for tobacco drainage presents interesting patterns on the mountain side. This is the so-called "diamond ditch" system with which soil erosion losses are heavy.
15. Stop for 20 minutes at Km. 51.4 to inspect the deep upland soils. Dr. R.M. Smith and Mr. J.P. Córdova will discuss soil conditions found here.
16. We now turn to Road #22, leading to Cidra.
17. (Km. 20.7) Observe the deep Catalina soil (p. 185-188) revealed by the road cuts.
18. Stop for 20 minutes at Mr. Fiddler's farm (Km. 16) where Mr. Allison, Director of Soil Conservation Service, will discuss the soil conservation work on this farm.
19. This is the town of Cidra (20,116) at an elevation of 425 meters above sea level. We turn to the left to Road No. 49.
20. On Road 49 (Km. 0.8) you see the transition from deep lateritic soils to shallow Múcara soils.

21. (Km. 2.7) Stop for 5 minutes. Typical shallow brown silty clay mountain upland soil, mostly in poor pasture, is well represented here. This is the tobacco area, where the tobacco crop is followed by corn and beans and then by native grasses of low feeding value. At Km. 8.7 we enter again on to Highway No. 1.
22. The next town is Cayey (32,965) at an elevation of about 400 meters above sea level.
23. As we leave Cayey and proceed on the road to Aibonito (16,320), we drive along the scenic La Plata Valley. Here we can see tobacco fields with their drainage ditches making geometric patterns on the mountain-sides.
24. The next is Aibonito, at an elevation of about 600 meters above sea level. The temperatures here are usually 5 to 10 degrees F. less than on the coast.
25. (Km. 86) This is the approximate point of division of the change of rainfall. We are leaving the high rainfall area of 80 to 100 inches to enter the 38 to 40 inches drier area. The soil pattern now changes from the Múcara to the Descalabrado (p. 240) soils, brown alkaline silty clays derived from fragmental tuff or tuffaceous shales containing free lime carbonates.
26. (Km. 88 to 90) Notice the change in vegetation in this area. The vegetation here is mostly xerophytic. Among the most conspicuous trees is the almacigo or gum-tree (Elaphrium simarouba) with its shiny reddish brown bark. The shrub-like vegetation includes many types of cacti and wild pineapples. Corn is grown in this dry area. Yields of 20 bushels per acre are obtained without fertiliser or irrigation in favourable years. (For further details of the vegetation of this area see pages 18, 19, 22 and 25.) The water in the background is that of the Caribbean Sea.
27. (Km. 92.1) Entering the Coamo terrace soils (p. 277). The Coamo clay is planted to Guinea grass and provides excellent range pasture for cattle and horses. In favourable seasons good crops of corn are grown.
28. The town of Coamo (25,340) where some fighting took place in the Spanish-American War.
29. We are now at Coamo Springs, where lunch will be served. This is the only hot spring in the Island and is a famous resort.
30. (Km. 102, Road No. 1) This stop for 20 minutes is to investigate a Coamo profile. Dr. J.A. Bonnet and Dr. M.A. Lugo in charge. Dr. Bonnet will give general details of the proposed Coamo irrigation project. Dr. R.M. Smith will give a demonstration on how to take 3 inch, undisturbed soil cores with the "Bradfield" sampler.

31. Along this road the purple-coloured soil is the Amelia clay.
32. Farther along this road the hills in the distance (right) of cretaceous limestone contain deposits of manganese dioxide which have been mined.
33. (Km. 107.6) On your left is a cut revealing a cretaceous crystalline marble.
34. (Km. 116) Here are a few areas of Juana Diaz clay loam and silty clay (p. 246-247). It is a neutral to alkaline soil, grayish-brown, and underlain by a substratum of friable yellowish-brown, fine-grained sandstone.
35. The next town is Juana Diaz (28,540).
36. At Juana Diaz we enter the area of alluvial soils, planted to sugar cane under irrigation, of the Paso Seco (p. 285) and San Anton (p. 322-25) series. These are among the most highly productive soils in the Island.
37. Immediately beyond the cemetery on the left, some of the sugar cane is grown on a heavy, black clay called Poncena (p. 259-60); classified as a chernozem.
38. The next town is Ponce (119,087), the second largest city in the Island.
39. Leaving Ponce we are on road No. 36. The soft Tertiary limestone here is used by the Ponce Cement Company in the manufacture of cement. Quarries are seen in the distance on the right.
40. (Km. 20.9) This saline area contains many salt spots (left).
41. (Km. 19.3) We now enter the rendzina soil area, where the soft limestone is covered by shallow brown to black soils. The major soil types of this area are the Aguilita clay and stony clay (p. 233-36).
42. (Km. 7) The cacti vegetation here is very predominant.
43. The next town is Guayanilla (16,941). We now take highway No. 2 (at Km. 237.2).
44. As we leave Guayanilla, we leave the rendzina soils and return to the Descalabrado soils formed from tuffaceous parent material.
45. The next town is Yauco (31,329).
46. At Km. 28.6 we enter Road No. 39. Most of the sugar cane land in this area is owned by the Puerto Rico Land Authority, a government agency.



47. (Km. 28). On the left is the new site of the Ochoa Fertiliser plant, largest fertiliser manufacturer in the Island.
48. At the town of Guánica, the United States troops first landed in 1898, during the Spanish-American War.
49. In the hills around Guánica, the Cretaceous and Tertiary limestone meet.
50. (Km. 26.3) This is Guánica Central, the largest sugar factory in Puerto Rico.
51. (Km. 20) This beautiful valley is the Lajas Valley, where an irrigation project is now under development. Most of the land is now used for grazing, but the completion of the Lajas Valley Irrigation Project will probably make this a sugar cane growing area.
52. The soil on the base of the mountain slopes is Fraternidad (p. 283-84), and it meets the Aguirre clay soils (p. 340-41) of the valley.

Second Day: Saturday, April 1, 1950

53. At the Lajas Substation of the Agricultural Experiment Station of the University of Puerto Rico (Km. 3.0 - Road 19), Dr. Smith will give a demonstration of the use of the Utah Soil Core Sampling Machine. Stop for one hour. Dr. Bonnet will give a short resumé of soil conditions in Lajas Valley.
54. The next town is Lajas (14,736).
55. As we go north on road 39, we see the shallow reddish brown soil, Lajas Clay (p. 239), derived from Cretaceous limestone.
56. In San Germán we enter into highway No. 2 and pass by the Polytechnic Institute, where we can see the shallow Rosario clay (p. 247) derived from serpentine rock.
57. Approaching Mayagüez, we enter the shallow tuffaceous soils again. The predominating soil is Múcara (p. 213).
58. We are now in Mayagüez, the third largest city in the Island, with a population of 89,494.
59. We are now going to see the Nipe clay laterite (p. 199-201) on the Las Mesas Plateau, southeast of Mayagüez. The soil can be seen in exposed road cuts on either side of the road as we drive up to the plateau.
60. (Left) The deep exposed cuts show the serpentine parent material from

which the Nipe is derived. The shallow soil is Rosario (p. 247).

61. (Km. 1.6) Stop for 20 minutes to see a Nipe clay profile in detail, then continue to the top of the hill to see abundant iron concretions or perdigones (p. 465). Back to Mayagüez we pass through the Federal Experiment Station.
62. Lunch at the College of Agriculture and Mechanic Arts.
63. We continue on highway No. 2 - A few kilometers after passing the bridge over the Ñasco river and the sugar factory, Central Igualdad, we see the Descalabrado soils (p. 420), with clear evidence of erosion by mass movement of soil.
64. The next town is Rincón (9,256).
65. The grapefruit displayed on the road-side stands are grown on Cataño loamy sand (p. 343), a calcareous soil along the coast.
66. The next town is Aguada (20,129). Some historians claim that Columbus landed in Aguada.
67. This is the town of Aguadilla (42,004). Other historians claim that it was here that Columbus landed.
68. (Km. 122.6) Highway 2 R - Stop for 15 minutes. The yellowish-brown soil seen here is called Coto clay (p. 302). The limonitic colour predominates in this soil. The soils with red colour toward the coast are the lateritic Matanzas clay (p. 197-198).
69. (115.2) We are passing the Isabela Substation and Seed Farm of the Agricultural Experiment Station of the University of Puerto Rico.
70. (Km. 106.9) (Right) Here we see a good example of the striking colour patterns caused by differential weathering processes. This red soil is a Vega Alta Sandy clay (p. 304).
71. The limestone here has small caves. (Km. 103.2) Leaning trees on the top of the hills here show the effects of trade winds.
72. (Km. 98) The conspicuous, high cone-shaped mogotes, (haystacks) and long, narrow pepino (cucumber-shaped) limestone hills can be seen in this area. Most drainage from these hills goes into underground streams.
73. In this belt of pure calcium carbonate rocks and massive reef beds, the Coto soils give way to Espinosa (p. 302-6), and the Matanzas to Bayamón (p. 303). The rainfall is higher. The soils are more acid, and there is sometimes more sand in the rock and in the soil profiles.

74. (Km. 81.7) (Left) The sand dunes seen bordering the ocean contain visible quantities of magnetite which can be recognized as black specks.
75. Approaching the city of Arecibo (80,957) we see the Islote sandy loam (p. 296) derived from sandy limestone.
76. The city of Arecibo is the fifth largest city in the Island.
77. (Km. 60.4) Stop for 10 minutes. This road cut reveals a Bayamón sandy loam (p. 306).
78. (Km. 61.2) We now see large acreages of pineapples (Spanish Red variety) planted on Bayamón soils. The pineapples are sprayed with iron sulphate solution to prevent chlorosis.
79. (Km. 53.4) We are now in the deep alluvial Toa soils (p. 315-16) in the Manatí Valley. These are very productive sugar cane soils.
80. (Km. 50) We are passing the outskirts of the town of Manatí.
81. (Km. 48.5) Stop for 10 minutes. Here begin the white sands. This pure quartz sand, known as the St. Lucie fine sand (p. 311), occurs here and in Florida. It is the raw material for glass manufacture in the Island.
82. (Km. 37) The alluvial soils here are the Coloso (p. 329-30), cropped mainly to sugar cane.
83. (Km. 23) The rich soils of this Toa Valley are the alluvial Toa soils.
84. We now continue on to Río Piedras.

(b) Field Trip II - Caribbean National Forest, Luquillo Mountains

Sunday Afternoon, April 2, 1950

1. We leave Río Piedras by highway No. 3 toward the east. The hills at the Experiment Station and to the south of Río Piedras are volcanic, ashy shales covered with reddish brown Río Piedras clay (p. 215-16) and grayish to grayish brown Yunes clay (p. 246). Yunes clay is the raw material used in the ceramics plant located close to the junction of Highways No. 3 and No. 44. The soil of the terraces derived from the shales is Fajardo clay (p. 273). The level areas are Sabana Seca sandy clay loam (p. 293) and Bayamón sandy clay loam (p. 303-304).
2. (Km. 8.0) A good view of the Luquillo Mountains in the distance to the left. The three main peaks, from left to right are: El Yunque, 3,496 feet; El Cacique, 3,346 feet; El Toro, 3,352 feet. Between this point

and the sugar mill, Central Victoria, the shale is replaced by tuffaceous rock. The uplands here are covered with Múcara silty clay loam (p. 213), the lower hills with Juncos clay (p. 214), and the colluvial or level areas with Mabi clay (p. 253).

3. (Km. 11.2) The town of Carolina, located mainly on Mabi clay. Just beyond the town we cross a large bridge over the Río Grande de Loiza, the river that carries the largest volume of water in Puerto Rico. The soils along the river are Toa fine sandy loam, low-bottom phase (p. 316-17), where Para-Carib grass grows well. Slightly to the northeast along the river course toward the Atlantic Ocean are the productive Toa clay loam (p. 315) and Coloso clay loam (p. 331), alluvial soils where sugar cane gives good yields.
4. (Km. 17.7) The town of Canovanas. Just beyond this town, to the right, is a good view of an area of soils derived from tuffaceous rocks.
5. (Km. 25.6) The town of Río Grande.
6. (Km. 32.8) The town of Mameyes. We take Highway 112 southward toward the Luquillo Mountains.
7. (Km. 3.0) We reach the red soils derived from andesitic tuffs.
8. (Km. 4.0) The La Catalina forest nursery. There will be a stop here on the trip if time permits.
9. (Km. 5.1) Stop for 20 minutes. A good profile of Catalina clay (p. 185-188). At this place Dr. Bonnet took soil samples for his Ph.D. thesis, published in Soil Science 48 (1): 25-40, July 1939. Dr. Bonnet will present a brief resumé of the data obtained.
10. (Km. 8.4) Stop for 10 minutes. A good view of the lower montane rain forest to the left. This formation will be described briefly by Dr. Wadsworth.
11. (Km. 12.9) Stop for 10 minutes. A profile of Los Guineos clay (p. 193-194) where Dr. C.D. Jeffries has taken soil samples for identification of minerals. Dr. Jeffries will give a short resumé of his findings.
12. (Km. 15.0) A good example of concentric weathering of quartz diorite to the right on the bank beside the road.
13. (Km. 15.2) Stop for 20 minutes. A mountain podzolic soil with an iron hardpan. Dr. Bonnet will describe soil conditions, and Dr. Wadsworth the vegetation here.

14. (Km. 4.0) Stop for 20 minutes if time permits. The soil problems at the La Catalina forest nursery will be discussed by Dr. Wadsworth.

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