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STUDIES IN WEST INDIAN SOILS

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Investigations into the origin, classification, properties and agricultural relationships of the soils of the West Indies region have occupied a great deal of the time and facilities of the Chemistry Department of the College since its inception in 1922. Indeed, the earliest attempts to bring together the available information concerning the soils of the West Indies, and to extend our knowledge of their origin and crop relationships within the different insular areas were made before the College was founded, and whilst the Imperial Department of Agriculture was still in existence, with headquarters in Barbados.

(1) The first publication describing West Indian soils was entitled " The Soils of Dominica, their Genesis and Fertility, considered in Relation to Reaction". It formed an article in the now defunct West Indian Bulletin, Vol. XIX, issued in 1922. It was based mainly on geological considerations, and involved a study of soil acidity in its possible bearing on the growth of the cacao crop and the lime crop. In the year 1920, when this investigation was undertaken, colorimetric methods for determining soil reaction by means of the new pH indicators elaborated by Clark and Lubs had only just been perfected. One of the main reasons for studying the soils of Dominica at that period was to apply the new technique and the newer knowledge of the role of acidity in soil fertility to specific crop problems and to questions of soil formation from different kinds of parent rock materials exposed to different amounts of rainfall. The investigation was one of the first of its kind to be initiated within any special area for such purposes, but it cannot be claimed to have been exhaustive, and the soils of Dominica still offer innumerable problems awaiting detailed study.

(2) The second publication concerning West Indian Soils was entitled "The Soils of Montserrat their Natural History and chief Physical Properties, and the Relationship of these to the Problem of Die-Back of Lime Trees". It appeared also in the West Indian Bulletin, Vol. XIX, 1922, pp. 189-213. The chief object of the investigation which forms the topic of this second paper, was to study the environmental conditions associated with the dying-back of twigs of lime trees, and to attempt some explanation of its incidence. The field work was performed in collaboration with the Plant Physiologist of the Imperial Department of Agriculture, Dr. T. G. Mason, later the first Professor of Botany at the College, and now Plant Physiologist to the Cotton Growing Corporation at their Research Station in Trinidad. Mason demonstrated a distinctive difference in the zonation of the young woody tissues of lime trees exhibiting the die-back condition and that of the wood of normal healthy trees. This difference could approximately be correlated with differences in the moisture conditions of the environments of the two contrasted kinds of trees, as decided by topography, protection front drying winds, and physical type of soil which decide its permeability to water. Physical soil-type was further found to be an expression of geological origin, so that the account of the soil aspects of the problem involved a brief discussion of the genesis of the soils of Montserrat. Its main purpose was nevertheless a study in crop ecology.

(3) Between the years 1922 and 1930, the organisation of the Chemistry Department of the College, the preparation of courses of teaching, the study of certain fundamental problems of Soil Physics, and the initiation of researches into the Froghopper problem of sugarcane in Trinidad delayed further the study of West Indian soils along the lines already initiated. Preliminary work on the soils of cacao and forest lands in Trinidad and Tobago conducted during this period (mainly with a view to providing subjects for the dissertations of specialist Post Graduate students of chemistry) eventually culminated, however, in the publication in February 1931, of the first of a new series of " Studies in West Indian Soils", namely, No. III, "The Cacao Soils of Tobago", in which the collaboration of two Post Graduate students, Messrs. C. G. Akhurst and G. Griffith was involved. This publication formed a supplement to the College Journal, Tropical Agriculture, Vol. VIII, 1931. Its general arrangement, scope and method of presentation

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of field and laboratory data were somewhat novel; they have been retained more or less unchanged up to the present time in succeeding articles or reports, conveniently referred to as "grey-books" on the Soils of the West Indies.

In this new series of soil studies initiated in 1928, a profile method of soil examination has been introduced and developed. Selected sites are explored by digging six-foot pits. The soil section thus exposed generally displays at its base the more or less unaltered parent rock. In many cases, ten-foot pits (such as are favoured by oil geologists in Trinidad) would have been preferable, but they are much more expensive to dig, and more difficult to sample. The profile is marked out into layers differentiated by changes in appearance and other easily discernible features, except where the changes are uniformly graded, in which case, arbitrary subdivision into multiples of three inches is generally made. The surface soil, containing the bulk of the "feeding roots" of crop plants or forest trees, is more minutely subdivided, for example, into layers of the following successive depths : 0-14, 14-3, 3-6, 6-9, 9-12, 12-18 and 18-24 inches, below which the deep subsoil is marked out into foot layers. A single six-foot profile may thus comprise between eight and 12 different layers, each of which is described and sampled separately. Full notes are made at the time of sampling on the more obvious features of the soil, according to a descriptive nomenclature and a simple colour chart that have been evolved for the purpose. The individual soil samples are separately collected, bagged and labelled, and eventually transported to the laboratory, where they are air-dried, pulverised and sifted prior to detailed laboratory study.

The methods of laboratory analysis include both physical and chemical routine determinations. They have been specially selected, exhaustively tested, and sometimes modified in order to render possible the examination of very large numbers of soil samples in a uniform manner, involving a minimum expenditure of time. Progressive counts of the methods finally applied are given in the published reports or articles describing the studies in West Indian Soils since the inception of the soil profile procedure in 1928. By the end of the year 1935, some 38o soil profiles in various parts of the British West Indies region had been dealt with in this manner, including the detailed examination of some 3,30o separate soil samples, and the work is still proceeding. This achievement has been possible mainly because of the existence of exceptionally suitable laboratory facilities provided by the College, and the organisation of a reliable staff of junior laboratory assistants working under the direction of a highly qualified analyst (Mr. G. Rodriguez). The junior staff is recruited mainly from youths of East Indian descent who have previously received an all-round elementary education in the schools of Trinidad.

The chief advantage of the rapid accumulation of a large mass of field and laboratory data lies in the fact that it permits detailed comparisons to be drawn between soils of different origins, formed under different climatic conditions, and subject to differing degrees of alteration through exploitation or utilisation for the growing of various types of agricultural crops. Thus, it has recently been found possible to diagnose with a fair degree of reliability the nutrient conditions of any particular type of soil in relation to the growing of cacao, citrus, banana, arrowroot and sugarcane in the West Indies region. Certain "limits of adequacy" with regards to soil nitrogen, phosphate and potash have been provisionally established for each of these crops, and the information is available for application to regions outside the West Indies. How far the tentative numerical relationships and the diagnostic features of suitable and unsuitable ("good" and "bad") soils may apply elsewhere, is a subject for future consideration when the methods have been more widely applied. The co-operation of soil chemists working in other tropical countries is being sought, and plans are being suggested for the examination in the College laboratories of representative soil samples imported from remote regions such as West Africa.

In attempting to establish relationships between soil factors and crop productivity, full use is made of yield data and the analysis of yield, such as have been developed for the cacao crop by the College Department of Economics under Professor C. Y. Shephard.

The soil data not only have proved serviceable in the diagnosis of soil conditions; they have also yielded much information concerning the processes of soil formation. The methods differ fundamentally from those employed by other schools of pedology, in that the soil profile is described, not simply as a morphological unit on appearance and structure alone, but mainly in terms of determinable physical and chemical constants. Thus, the laboratory values enable one to describe the texture profile, the reaction profile, the organic matter and nitrogen profile, the soluble salt

profile, and the available phosphate and potash profile, as separate, though related, entities. Such physical and chemical descriptions of the soil profile, augmented by special laboratory determinations of exchangeable bases in representative, composite surface soil samples, and by complete chemical analyses of parent rocks, together with, in some cases, that of clay fractions, provide much more reliable information regarding the nature and effects of the processes of soil formation than mere inspection alone. By their employment and application, soil profiles may the more accurately be compared and classified. The numerical data for the successive layers of soil of each profile may be set out in columns of colours on profile charts, which include a column of actual specimens of the soil itself, mixed with transparent varnish and painted on to the cards. A scheme of colours for most of the determined soil constants has been devised for use in the preparation of these profile charts. Sets of completed charts are filed for future reference.

Referring again to the third article of the Studies in West Indian Soils, namely "The Cacao Soils of Tobago", the soil profile data clearly indicated striking differences between "good" and "bad" cacao soils, the accepted definition of " good soil being one which supports mature cacao trees yielding over eight bags (each of 165 lb. weight) of dried caca, beans per r,000 pickets or tree sites. Two chief factors appeared to account for high yielding capacity in the better cacao soils of Tobago, namely, (I) a high nutrient status (as estimated by electrical conductivity of water extracts of soil), and (2) a relatively high ratio of carbon to nitrogen in the organic matter contained in the surface six-inch layer of soil.

At the time when the Tobago cacao soils were being examined, individual determinations of available phosphate and potash had not been introduced into the routine laboratory work, so that the specific nutrient factors of the soil could not then be identified. Later investigations, not yet published, have demonstrated that many of the Tobago soils are very deficient in potash, which seems to be associated with a well-defined leaf symptom, described as "marginal leaf-scorch of cacao". (See Fourth and Fifth Annual Report on Cacao Research for 1934 and i935.) This symptom was first noted by Mr. J. A. McDonald (Chemist for Cacao Research) in 1933, in sand cultures of cacao seedlings treated with a nutrient solution lacking potassium. It has since been observed widespread in the field in various parts of Trinidad and Tobago, particularly on trees growing on soils containing less than a certain critical amount of available potash, as measured by a standard laboratory method. Some of the Tobago cacao soils are also deficient in available phosphate; deficiency in this nutrient seems to diminish the uptake of potash, so that, in certain cases, the effect of these two nutrients appears to be interdependent.

High ratio of carbon to nitrogen indicates an early stage in the decomposition of leaf and root vegetable debris; its association with high yields of cacao was originally noted for the cacao soils of Tobago by Dr. G. Griffith whilst attempting to correlate yield data with various soil factors. The reason for this striking correlation (which has since been conclusively demonstrated for the cacao soils of Grenada and of Trinidad) is difficult to find, but a suggestion that it is directly concerned in the prevalence of *mycorrhiza* in the soil, which is causally connected with the ability of the cacao root system to absorb nourishment from the soil, has received some verification from the work of Mr. E. E. Pyke, published in the Fourth Annual Report on Cacao Research, 1934, pp. 41-48. It is evident from these observations that the study of the cacao soils of Tobago has provided numerous promising lines of investigation, and has educed many suggestive ideas, so that the selection and application of the methods employed therein have been amply justified.

(4) The fourth article of Studies in West Indian Soils concerns the Cacao Soils of Grenada; it was published in December, 1932. The soils of Grenada have been formed from andesitic and basaltic lavas, and from their pyroclastic or fragmental equivalents (agglomerates and tuffs), though many of them belong to the river alluvial type, derived from the same volcanic parent materials. They are therefore somewhat different from the soils of Tobago, which have been formed from a more acidic kind of igneous rock, namely diorite, and from metamorphic rocks (mostly schists) that resemble somewhat the rocks of the Northern Range of Trinidad. Furthermore, the greater altitude and consequently the greater rainfall of the interior lands of Grenada have brought about a greater degree of rock alteration, weathering and leaching than have occurred in Tobago, so that the Grenada soil profiles are generally much more "mature" and more highly stratified, or differentiated into layers, than those of Tobago. Nevertheless, the same features distinguish the "good" cacao soils from the "bad".

The individual soil samples collected in Grenada were all analysed for available phosphate. This additional method of laboratory examination, applied for the first time as a routine procedure, revealed the new fact that phosphate is characteristically deficient in the poorer-yielding cacao soils of Grenada. These poorer soils generally occur at the greater elevations in areas of high rainfall; doubtless intense leaching has here deprived the soil of a large part of its content of phosphate and of lime, and has thus produced highly acidic conditions in the surface layers, as well as a marked deficiency of available phosphate. The chief features differentiating "good" from "bad" cacao soils in Grenada are their higher carbon/nitrogen ratios and their higher contents of available phosphate. These two relationships with yield data have been established by statistical analysis. Other factors, such as deficiency of potash and highly acidic reaction, may also have contributed to the low yielding capacity of some of the poorer upland soils.

(5) The fifth article of the series is entitled "The sugarcane Soils of Antigua". It was published in April 1933. Its scope and main findings differ considerably from those of the preceding studies of cacao soils formed from igneous rock materials. The soils of Antigua are mostly derived from somewhat abnormal kinds of sedimentary rocks, including saline aqueous tuffs and highly calcareous marls and soft limestones. They are characterised by their highly alkaline reaction, due to the facts that either they contain excessive amounts of free calcium carbonate (limestone and marl soils), or they belong to the category of "black alkali soils" (slightly calcareous, saline, sedimentary tuff soils). The dry climate of Antigua (rainfall 40 to 30 inches a year) is conducive to the development and perpetuation of such soil-types, and the problems associated with their successful utilisation, even for the purpose of producing the widely-tolerant sugar-cane crop, are among the most difficult and perplexing that the agriculturist has to face. They require very careful tillage, and the question of their proper manuring needs special consideration, and entails cautious methods of experimental approach. The various aspects of their handling and treatment are now being actively studied in the field by the Agricultural Superintendent (Mr. F. H. S. Warneford), and by a Specialist Research Officer (Mr. C. F. Charter) employed by one of the large Sugar Companies, acting with the advice and guidance of the Adviser in Sugarcane Experiments to the Commissioner of Agriculture (Mr. P. E. Turner). Recently, additional chemical and physical investigations into the peculiar features of the Antiguan soils have been undertaken by the writer, in continuation of the earlier studies described in Part V of the series under consideration. This additional work may be described in a further publication on the Soils of Antigua, to be issued later in the present year (1936), or early in 1937.

(6) The sixth article of the series is entitled " Some Soil-Types of Jamaica". It comprises an account of the origin, formation, classification and agricultural relationships of the main kinds of soil that occur in this large island of the Greater Antilles. It is the outcome of a joint investigation, undertaken in September 1932, by the Agricultural Chemist of the Jamaica Department of Agriculture (Mr. H. H. Croucher) and the Chemistry Department of the Imperial College of Tropical Agriculture. This publication was issued in August, 1933. The soil-types investigated are mainly devoted to the growth of bananas and sugarcane. The field and laboratory data enabled tentative comparisons to be drawn between the soil-types of Jamaica and certain types belonging to well-known world-groups, such as have been defined by Russian and American pedologists. Furthermore, they provided valuable information concerning the climatic and soil requirements of two important tropical crop plants —banana and sugarcane—which has since been employed in attempts to assess and evaluate other soils planted to these crops in other parts of the West Indies region, notably British Honduras and Trinidad.

The agricultural soils of Jamaica may clearly be classified into soils derived from calcareous parent rocks (such as the white limestones that comprise the great interior plateau occupying over four-fifths of the island), and soils derived from non-calcareous rocks (such as the old alluvial deposits that occupy the vast southern coastal plains around Kingston and in the parishes of St. Catharine and Clarendon). Within the regions occupied by these two geological subdivisions, the agricultural lands may be further classified into wet lands and dry lands, according to the magnitude of the annual rainfall. Finally, within the wet and the dry districts, the lands may be differentiated into flat lands and hilly lands.

The interplay of the three factors, nature of parent rock, rainfall, and topography, has resulted in the development of several distinctive soil-types, showing natural gradations or intermediate stages, and ranging between very wide extremes. Saline and alkaline

dry-land soils, similar to some of those occurring in Antigua described in the last section, represent one extreme, and deep red earths, derived from upland limestones or from ancient basement conglomerates under conditions of high rainfall, represent the other extreme. The multiplicity of environments thus displayed in Jamaica favours great diversification in agricultural cropping, and offers numerous interesting problems, both in pedology and in crop ecology.

(7) The seventh article of Studies in West Indian Soils, namely, "The Cacao Soils of the Montserrat District of Trinidad" (published in October 1933) reverts to a fuller discussion of the inter-relationships between climatic and soil conditions and the growth and reproductivity of the cacao tree. The fact that cacao was planted in Trinidad under a wide range of conditions when prices were high, has furnished valuable material, both for ecological and economic study. Since prices have dropped, greater interest has been shown in the costs of production of cacao, and the quantitative data recently collected have revealed the great importance of the nutrient status of the soil which differs widely for the different soil-types. The main aim of the soil investigation described in publication No. VII, was therefore to establish as closely as possible the relative importance of the soil factors responsible for high yielding capacity, and contrarily, for low yielding capacity for cacao. The distribution of "good" and or "bad" cacao soils, and the full description of soil types falling within these two broad categories, were attempted for some 80 square miles of irregular country comprising the Montserrat District. A detailed soil map of the area was prepared by Mr. J. A. McDonald, and numerous soil samples, representing some 85 different soil profiles, were fully analysed in the laboratory. The results of this detailed investigation amply substantiated those obtained from the earlier study of the Cacao Soils of Tobago (Publication No. III), and more clearly identified the main soil factors associated with high cacao yields. In particular, they further stressed the importance of the nature and amount of the organic matter component of the surface soil, and the total and relative quantities of available phosphate and potash in the soil. An important outcome of the work was the inauguration of a series of specific manurial experiments on cacao as part of the College Cacao Research programme. These field experiments have since been greatly extended by Dr. F. J. Pound, Agronomist of the Trinidad Department of Agriculture, in connection with the new Cacao Relief Scheme, which was launched in 1935. The further exploration of the cacao soils of Trinidad into districts where other well-defined types of soil occur is being actively pursued. Descriptive accounts of the progress made and of any new results which may accrue from these continued investigations will form the topics of future articles of the series.

The cacao soils of Trinidad differ from those of Tobago and Grenada in that they have been derived mainly from sedimentary rocks. Only one very small area of outcropping igneous rock occurs in Trinidad (near Toco on the north-east coast), but its derived soils have not yet been studied in detail. Certain of the sediments contain the mineral gypsum; soils formed from gypseous rocks appear to be very unsuitable for cacao production. Thus, the cacao soils of Trinidad offer a wide range of problems, and it is hoped that their exhaustive study may provide important generalisations which will be of value to cacao growers, not only in the West Indies, but also in other parts of the Tropics.

(8) The next article of Studies in West Indian Soils (No. VIII), published in December 1934, concerned an entirely different set of problems, associated with another kind of tropical crop, whose requirements are very different from those of the crops that had previously been examined. It is entitled "The Agricultural Soils of St. Vincent", and it discusses the soil relationships of the arrowroot plant. This article was published in December 1934, with the collaboration of an ex-student of the College, Mr. C. K. Robinson, now Assistant Superintendent of Agriculture in St. Vincent.

The parent soil-forming rocks of St. Vincent are mostly volcanic agglomerates, loose ash and dust. In this respect they differ from those of the neighbouring island, Grenada, which are mainly compact igneous lavas. Some of the St. Vincent volcanic ash was spread over the northern part of the island during the last eruption of the Soufriere Mountain in 1902 and 1903. Heavy rains have since removed the greater part of the ash accumulations, but at least one-third of the total area of the land still consists of recent volcanic ash, which has not yet been very much altered by weathering agents. The rest of the land area is made up of much older fragmental volcanic rocks, which have been considerably altered and weathered, and often cemented into hard gritty material known locally as "terras". Few lava flows occur in St. Vincent. The kinds of igneous rock comprising both the lavas and the fragmental materials are similar to those occurring

in Grenada, namely andesites and basalts, but chemical analysis has revealed the striking fact that the St. Vincent rocks contain significantly lesser amounts of total potash.

The soils of St. Vincent thus differ very materially from those of Grenada described in article No. IV of the Studies in West Indian Soils. Whereas many of the Grenada soils are red or red-brown clays and looms, the soils of St. Vincent are mostly ochre-yellow, brown or black sands, containing little mineral colloidal matter. Evidently rock weathering has proceeded much farther in Grenada than in St. Vincent, a fact which is clearly demonstrated by a microscopical examination of profile samples representative of the different types of soil occurring in the islands. The study of the volcanic ash soils of St. Vincent furnished an excellent opportunity for applying the methods of mineralogical analysis recently advocated by Dr. Vageler in his book "Tropical Soils" (1933), who claims that "the permanence of fertility in a soil varies with its content of minerals which are still liable to decomposition". The mineral analyses were performed by a Post Graduate student of the College (Mr. R. A. Hamilton), who found that the St. Vincent soils consist almost entirely of unaltered fresh mineral grains (soda-lime felspars, hypersthene, augite, magnetite and olivine). On the other hand, the red soils of Grenada contain less than 25 per cent. of unaltered mineral grains, and generally of more than seven per cent., though certain of the sandier ash and tuff soils may contain up to 34 per cent. of fresh grains. Only in very few cases, however would the soils of Grenada be considered to be definitely deficient in fresh minerals, according to the standards suggested by Vageler, but some of them might be regarded as border-line cases, whose degree of permanence of fertility may be low.

The fundamental differences between the soils of St. Vincent and those of Grenada are clearly reflected in the kinds of crops grown, and the types of agriculture practised in the two islands. Whereas cacao is the main crop of Grenada, arrowroot and cotton are the crops chiefly cultivated in St. Vincent. These two crops require a drier habitat than cacao, and well-drained, highly permeable sandy soils, such as abound in St. Vincent, are eminently suited to their moisture requirements, and their methods of planting and reaping, even in districts where the rainfall is high. Chemical analysis has revealed the fact, however, that the St. Vincent soils are not altogether satisfactory with regards to their nutrient status, and critical field manurial experiments have demonstrated that nitrogen and potash are the chief nutrients that are generally deficient, both in arrowroot and in cotton fields; where potash is abundant, additional nitrogen can he utilised with benefit to the crop. A useful rough index of soil suitability is furnished by the potash/ nitrogen ratio of the soil. The production of abnormal arrowroot rhizomes ("cigar roots") also appears to be associated in some manner with unsatisfactory nitrogen and potash supplies in the soil, not only with regard to the total amounts of these nutrients, but also with regards to their ratio-balance or proportionate amounts. Organic matter has long been suspected of exercising a particularly important role in the fertility and productivity of the soils of the cotton and arrowroot lands of St. Vincent; organic mulches have frequently given very large increases in crop yields. A critical study of this question, based on laboratory data and field experimental results, has indicated that the main effect of organic manure is nutritional, due to its high content of nitrogen, although a possible solubilising effect on the soil minerals of carbonic acid, produced by its oxidation in the soil, may increase the availability of their potash and phosphate contents.

(9) The ninth article of the series describes "Some Soil-Types of British Honduras, Central America", and was published in December 1935. It was the outcome of an arrangement between the Government of British Honduras and the Principal of the College, whereby a reconnaissance survey of the chief soils of the Colony should be made with a view to deciding their suitability for the continuation and possible extension of banana, grapefruit and sugar-cane cultivations. The investigation afforded an opportunity of testing some of the conclusions reached in former studies with regards to the ecological equirements of these three important tropical crops. The field work was undertaken with the co-operation of Mr. H. P. Smart, Agricultural Officer of British Honduras, and of Messrs. J. B. Kinloch and R. S. Pelly, Forestry Officers. The lands of British Honduras are mainly undeveloped.

Less than seven per cent. of the total area of British Honduras is occupied by existing or recently-abandoned cultivations, whilst more than 50 per cent. is covered by tropical rain forests which occupy most of the interior lands. The rest of the area (43 per cent.) comprises swamp forests of the coastal and riverain strips, wet and dry savannahs, and intermediate lands.

The chief agricultural soils occur on river alluvial lands, such as those within the Stann Creek Valley which were once famous for commercial banana production until Panama Disease devastated the cultivations. The Stann Creek area has been recently reopened for peasants' settlement, and several flourishing grapefruit plantations have replaced many of the former banana fields. The soils are variable and generally highly acidic, but their nitrogen and potash contents are high, though their phosphate content is low. The laboratory data obtained for these soils have suggested lines for field experimentation with a view to formulating suitable manurial treatments. Comparisons with data for other banana and grapefruit soils occurring elsewhere in the West Indies region have proved very useful in assessing the nutrient status of the Stann Creek alluvial soils.

The greater part of British Honduras is covered with black and red soils derived from soft marls and hard Tertiary limestones. These calcareous deposits form flat plain country of low relief,extending far northwards into Yucatan. Most of the land is closely afforested and abounds with relics of the ancient Maya civilisation, such as terraces and mounds. Around Corozal, in the extreme north of the Colony, occurs a deep, rich, black marly soil which grows magnificent sugar cane crops, but a sugar industry has not yet been developed and centralised there, though plans are now being advanced for the erection of a large sugar factory, which should greatly encourage the development of the Corozal district. Other parts of the marl and limestone region, within access by road of Belize (for example, the Boston District) may soon be planted in bananas. The soil is neutral or alkaline and quite fertile, but it is frequently underlain at shallow depths by flints or hard limestone which seriously restrict the root room.

The southern part of British Honduras experiences very high annual rainfall (over 100 inches). Certain of the alluvial soils bordering the more navigable rivers are partly developed for agriculture, but the greatest expanse of productive land occurs around Punta Gorda (Toledo District), which was originally settled by Americans after the Civil War in the United States. The soil is derived from Miocene sediments of variable composition, including some that are highly calcareous. Many of the soils are quite fertile, though somewhat lacking in potash. They support fair crops of sugar cane, but they would require special treatment to enable them to produce profitable bananas. Hill rice is being grown in certain parts of the district, and a rice experimental station has recently been established near Punta Gorda.

The forests of British Honduras have been classified into different associations dominated by distinctive tree species, certain of which, such as mahogany, have considerable commercial value. The chief factors which appear to have affected the distribution of the forest types are rainfall, topography, kind of soil, and interference by man. The chief controlling agency is probably soil water supply, whose magnitude depends on the interaction of these factors, and particularly on the physical properties of the soil, which differ significantly between porous sands, impervious acidic clays and permeable calcareous clays or marls, all of which are represented among the soils of British Honduras.

It is evident from this summary of some of the main findings of these studies that a very wide range of problems is presented to the scientific investigator of the soils of the West Indies region. The climate varies widely in different parts of the legion and within each insular area or country. The soil-forming rocks include almost every main type known to the geologist. Every stage of agricultural development is represented, ranging from forest exploitation, shifting cultivation and peasant settlement to estate organisation, orchard management and intensive gardening. Numerous different kinds of tropical and sub-tropical crops are grown, both herbaceous and arboreal, and many different systems of cultivation are practised, involving hand tillage, implemental tillage, thorough drainage, irrigation, cover cropping and all sorts of manuring. The value of exact field experimentation is gradually being realised, and the need of detailed soil surveys is becoming increasingly experienced as economic conditions and external competition is forcing the agriculturist to learn how to conserve soil fertility, to improve yields, and to diminish costs of production. Since the soil is the basis of all agriculture, the continued investigation of these problems will always demand first attention. The accumulation of such relevant data as can be obtained by reliable methods of field and laboratory research thus requires no justification, and the start that has already been made in the study of West Indian soils should lead the way to their fuller understanding.