STUDIES ON CEYLON SOILS

I.—MODERN METHODS OF SOIL STUDY AND CLASSIFICATION AND THEIR APPLICATION TO CEYLON SOILS

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INTRODUCTION

NUMEROUS references to the soils of Ceylon are found in various books and publications by administrators, forest officers, botanists and geologists [1, 2, 3, 4] of earlier times. They are confined chiefly to the general appearance and nature of the soils, their mineralogical and geological characteristics, vegetative relationships, productivity, etc. In the main, the observations are remarkably accurate and the opinions expressed often quite sound. The systematic examination of Ceylon soils dates back to coffee days [5, 6], since when a vast amount of analytical data of the soils of the Island has been accumulated. The more recent valuable contributions in this respect are the publications on the tea soils of Ceylon by Bamber [7] and the paddy and forest soils by Bruce [8, 9]. Soil analyses, until recently, had generally for their object the determination of the physical constitution of the soil and the deficiencies or abundance of plant food material in it. While the information they supplied was doubtless of practical value, it was of limited utility from the standpoint of soil science or *pedology* which is concerned not only with the agricultural value of the soil, but with its origin, constitution, properties and classification as well.

In at least two important respects does modern soil study differ from that of the past. In the first place the unit of study is now the *soil profile*, which is a vertical section of the soil from the surface down to the parent material. The soil profile represents the sum-total of the chemical and physical changes which have taken place in the entire soil mass, and a number of distinct soil layers or *horizons*, the depths of which vary, are often recognisable in it. In the old method of soil sampling the samples were taken to standard depths, *e.g.*, 0-9 in., 9-18 in. This, it will be obvious, would have involved the mixing in part or whole of various horizons, and while the analyses were of some value agriculturally, they gave no indication whatever of the pedological processes to which the soil had been or was being subject. Modern soil sampling is therefore carried out according to the depths of the various soil horizons.

The second feature of modern soil study is the stress it places on the characteristics of the clay complex of the soil. It is now well recognised that the processes which go to make up soil fertility, in so far as the mineral plant foods are concerned, are intimately connected with the clay component of the soil. Certain analytical determinations now regarded as essential for the valuation of this constituent of soil fertility did not find a place in older soil work. Such for instance are the exchangeable base contents and the silica/sesquioxide ratio of the soil.

The study of a soil profile involves not only the analytical examination of the different horizons, but also the determination of their structure, texture, consistency, etc., and the general mode of formation, geological origin, drainage, etc., of the entire soil. This necessitates an examination of the soil in the field. As Robinson [10] in his recent work on 'Soils' remarks: "Eventually, the pedologist must go into the field and study his material under natural conditions," and "the centre of interest must now shift more and more from the laboratory to the field". Based on the soil profile as the unit, the division of soils into a number of major groups has been made possible.

But little has so far been done in regard to the study and classification of Ceylon soils on modern pedological lines. Eden [11] was the first to apply these new methods to some local tea soils. An attempt at the classification of Ceylon soils in conformity with recognised world groups was made by Schokalsky [12], but as her data was limited, the classification is necessarily incomplete. Hers is however an interesting and useful contribution to the knowledge of our soils in the light of modern soil science.

SCOPE AND OBJECTS OF PRESENT STUDIES

The present studies have for their primary object the investigation of some of the characteristics of the major soil groups of Ceylon on the basis of the soil profile. It is considered that the results of these studies would offer sufficient data for an attempt at classification of local soils in relation to well-known world types. The scheme of classification suggested is necessarily tentative and will doubtless need modification as further data become available. It offers however a working hypothesis and as such should prove of some use to future students of local soils.

As it has been strongly urged that a publication on the more important types or groups of local soils is desirable for the use of agricultural instructors and students, and as the data to be published will, it is considered, be of interest to pedologists as well, a compromise in regard to the mode of presentation of the results of these studies has been made. It is proposed to publish, in the first instance, a series of six or seven articles on the subject. In the present paper which is the first of the series an account of the modern methods of soil study and classification and their application to local soils, is given. This paper is essentially meant for the practical agriculturist and the non-technical reader. In the second, a concise general account of the characteristics of the main local soil groups will be presented and a scheme of classification of these groups suggested. This paper should prove of interest to both classes of readers. The subsequent papers will be an elaboration of Paper II, and will contain the observational and analytical details of the profiles studied. It is thereby hoped that the series of articles would prove of interest and value to as wide a circle of readers as possible.

SOIL FORMATION AND CHARACTERISATION

Soils are formed from rocks through the processes of weathering, both mechanical and chemical. The two main factors governing these processes are climate and parent material. By climate is meant the rainfall, temperature and humidity to which a soil is subject. Climate influences the character of the soil to a more pronounced degree than does the rock material from which it is formed with many groups of soils. The Russian soil scientists were the first to enunciate the principle that soils of similar character would be formed from rocks of different geological type, provided the climatic conditions were uniform, and that dissimilar soils would be formed from rocks of the same or similar geological type, if the climatic conditions to which they were subject varied. While this principle was found to hold with a large number of soil types of the world, called the climatic soil types, there were some notable exceptions as, for example, the red calcareous soils. Instances have also been recorded of very diverse soils being formed under the same climatic conditions from similar geological rocks. For the purposes of this paper it is sufficient to compare the effects on soil character of a wet tropical with a moderately wet temperate climate. Under tropical conditions of heavy rainfall and high temperature, chemical weathering is very intense and so is leaching. The alkali bases, soda, potash, and lime are almost completely leached out and so also is a comparatively large proportion of the combined silica of the original rock. Organic matter is also very rapidly decomposed under these conditions. The ultimate result is a soil rich in the sesquioxides of aluminium and iron relative to combined silica, and poor in bases and humus. Of this nature are the laterite, lateritic and red earths soils of the tropics in general and of Ceylon in particular. These furnish excellent examples of climatic soil groups. Under moderately wet, temperate conditions, soils are formed containing good reserves of organic matter and clay. The latter is high in silica and comparatively low in sesquioxides. Such are the brown earth soils of Europe. Parent material influences the nature of the soil derived from it, irrespective of climatic conditions, in the case of soils associated with limestone and immature alluvial soils.

THE SOIL PROFILE

The soil profile, as already explained, is a vertical section of the soil from the surface down to the underlying parent material, whether unweathered or slightly weathered. It is divided into three layers or horizons known respectively as horizon A, B, & C. Horizon A is the surface soil or upper horizon of the soil mass from which material is removed by percolating water. It is generally subdivided into two or more sub-horizons, of which A0 is the layer of organic debris [13]. The other sub-horizons are designated A1, A2, etc. Horizon A is also known as the *eluvial* horizon as material is leached out from it. Horizon B underlies horizon A and is the layer of deposition or accumulation of material leached from A. It is known as the *illuvial* horizon and may again be subdivided into other horizons designated as B1, B2, etc. The C horizon is the undifferentiated parent material. This may be either the parent rock or partly weathered material. The characteristic features of a soil profile are mainly the results of chemical weathering and the redistribution of the products of such weathering by the agency of water, either percolating downwards or drawn upwards through the action of capillarity.

FIELD OBSERVATIONS

The different horizons of a profile are generally recognised in the field by their colour, texture or structure. Observations on the following soil characteristics are made in regard to each distinct horizon of a soil profile: depth, colour, texture, structure, consistency, root penetration, presence of concretions and chemical deposits, degree of rock decomposition, horizon boundary, moisture conditions, reaction and special features. Most of the above characteristics are self-explanatory, but the few unfamiliar terms will be considered in some detail.

Soil texture is the term indicating the coarseness or fineness of a soil and the proportion of the various constituents in it. Thus soils may be divided into sands, loams, silts, clays, sandy loams, heavy loams, gravelly loams, and various other textural classes. Hardy [14] has advocated the adoption of a single value factor for expressing the texture of a soil, known as the 'Soil Texture Index'. This factor is calculated from the sand content of a soil and its sticky point moisture, a term which will be explained later. A similar factor can also be obtained by multiplying the actual percentages of clay, silt and sand by certain constants and totalling these figures together. Examples of this will be given in the subsequent papers. On the basis of the texture index, the following soil classes are recognised:

Index of Texture	Soil Class
1-10	Sand
11-20	Sandy or Light Loam
20-30	Heavy Loam
30-40	Fine Silt
40-45	Heavy Silt
45-55	Clay
55-60	Heavy Clay
+60	Very Heavy Clay

If gravel or stones are present in such quantities as to effect the economic value of the soil type, the terms gravelly and stony are used.

In the field the texture of a soil is determined by its "feel", that is by pressing a small amount of the soil between the thumb and the first finger.

Soil structure is the term expressing the arrangement of the individual grains and aggregates that make up the soil mass [13]. The terms used in describing soil structure are as follows: granular, when the aggregates are of medium consistency, more or less rounded in shape and of diameter up to about 2 cm; columnar, when the arrangement of the soil mass is in more or less regular columns with vertical sides and rounded tops; prismatic, the arrangement of the soil being more or less in prismatic blocks; cubical; single grain; clod; nut or nodular, the aggregates being compact and of hard consistency and more or less rounded in shape like nuts; crumb, signifying an ideal soil structural condition allowing of free drainage and aeration.

Consistency is the term expressing the degree of cohesion of a soil. Common terms used to express consistency are loose, friable, soft, hard, compact, impervious. [13].

In addition to the data thus obtained for each of the horizons of the profile, the following observations are made in regard to the whole profile [15]:

(1) Location and elevation.

(2) Climate: rainfall and temperature.

(3) Geological origin of soil material. Under this head the four following classes are recognised:

  (a) Igneous rocks: *e.g.*, granite, norite.
  (b) Sedimentary rocks: *e.g.*, limestone, sandstone.
  (c) Metamorphic rocks: *e.g.*, gneiss, marble, quartz.
  (d) Unconsolidated deposits: *e.g.*, gravels, sands, clays.

(4) Mode of formation: whether transported by water, *e.g.*, alluvium, gravity, *e.g.*, colluvium, wind or ice; or whether the soil is formed *in situ*, i.e., is residual or sedentary. Some writers use the terms primary and secondary for residual and transported soils respectively.

(5) Drainage. This is described as excessive, good, imperfect, or poor.

(6) Topographic position. The general configuration of the area from which a representative profile is taken is expressed in the following terms: rugged, steep, rolling or undulating, sloping, level, depressed.

(7) Vegetation; nature, distribution, etc.

SELECTION OF PROFILE SITE AND SOIL SAMPLING

Before a soil profile is examined, it is necessary to make certain that it is typical of the area which it is intended to study. This has to be ascertained by a preliminary exploration of the area, for which purpose a soil auger is very helpful. Where this tool is not available, an examination is made of road cuttings, ravines, and other soil exposures in the area. When a profile is to be taken of an area on hilly ground, a site is selected about halfway down the slope. Care is taken that the place selected is, as far as possible, free from the influence of denudation. Thus badly eroded soils are avoided. An area which has not been subject to cultivation is preferably chosen for the location of the site. Where however uncultivated land is not available, a place is selected which has been least affected by cultivation.

Once a site has been decided on, a trench at least 4 feet deep or down to parent rock material when this occurs at a less depth, and 3 feet by 3 feet in cross section is dug. A 4-foot depth generally suffices for most local soils. If it becomes necessary to sample to greater depths or if the digging of a pit is not convenient, a fresh cut in a hillside, along roads, quarries or railroads will be equally suitable. Great care, however, is exercised that the profile has not been disturbed in any way either by the removal or addition of soil material. When the profile section is ready all the observational data, depth measurements, etc., discussed in the preceding paragraphs are made and then only is the sampling begun.

The actual sampling of the profile is carried out by cutting vertical slices of the soil, from each of the horizons in turn, starting from the A horizon. Local soil profiles often exhibit no marked horizon boundaries. It will however be found that with most soil profiles, at least two distinctly-coloured sections can be recognised. The A horizon, especially in uncultivated areas, is generally of an appreciably darker colour than the underlying horizons due to its accumulations of organic matter. It corresponds to what is known to practical agriculturists as the soil layer, while the B horizon generally corresponds to what is called the sub-soil. Enough soil is taken from each horizon of the profile for a complete chemical and physical examination. About 3 lb. of well-mixed, moist soil generally suffices. Each sample is labelled with the location or number of the profile and the depth range from which it was taken.

Numerous illustrative examples of the method of recording the data of a soil profile will be furnished in subsequent papers.

ANALYTICAL EXAMINATION OF SAMPLES

The samples on receipt in the laboratory are air-dried, if this was not previously done, lightly ground down with a wooden pestle, weighed and sieved through a 2 mm. sieve. The material passing through the sieve is stored for subsequent examination and the stones and gravel washed, dried and weighed and their percentage in the original soil calculated. The determination of the content of stone and gravel in a soil sample is an important one, as in tropical soils these constituents occasionally do form a very high percentage of the soil mass. In these circumstances the soil is infertile.

The soil proper (sieved material) is then subject to examination. It is not possible, nor is it desirable, in a paper of this nature for technical details of methods of analysis to be given. Those readers who would wish to pursue the matter further are referred to text books such as Robinson's 'Soils — Their Origin, Constitution and Classification' [10] or Russell's 'Soil Conditions and Plant Growth' [16]. What will however be attempted in this paper is an explanation, in the case of the less familiar analytical determinations, of what the particular method measures and its value from a soil standpoint.

The first step in the processes of soil analysis is the determination of the physical or *mechanical composition* of a soil. All agriculturists know that the mineral portion of a soil is comprised of the four following particle classes: clay, silt, sand and gravel. A mechanical analysis shows the relative proportions of each of these constituents in the soil. By international agreement the soil constituents are defined according to their sizes as follows:

Coarse sand	2-·2 mm.
Fine sand	·2-·02 mm.
Silt	·02-·002 mm.
Clay	Less than ·002 mm.

The method of mechanical analysis adopted in this laboratory is the one recommended by the Imperial Bureau of Soil Science [17]. The other routine determinations now considered of importance in soil work are indicated in the following paragraphs:

Moisture.—This is the amount of water contained in an air-dry soil dried to constant weight at 105°C. *Loss on Ignition*, which is a measure of both the organic matter content of a soil and the colloidally-held moisture, is determined by igniting the dry soil in a muffle furnace. *Organic Matter*. This is obtained indirectly from its carbon content by multiplying by the conventional factor 1·724. *Carbon* is determined by either a wet or dry combustion method. Robinson's wet combustion method is used in this laboratory [18]. *Nitrogen*. The ordinary Kjeldahl method is adopted for the estimation of total nitrogen. *Carbonates* when found in local soils — of infrequent occurrence — is determined by the Collin's calcimeter.

Reaction.—The reaction value of a soil is a measure of its acidity or alkalinity. It is now commonly expressed as the P_H value or the negative logarithm of the hydrogen-ion concentration of the soil. A P_H value of 7 denotes a neutral soil, while lower values indicate acid soils, the lower the P_H the more acid the soil. P_H values higher than 7 are shown by alkaline soils, the alkalinity increasing with increasing P_H. Colorimetric and electrometric methods are used for determining the P_H value of a soil. The determination of this soil characteristic is of importance inasmuch as certain crops will not grow, much less thrive, except on soils which have a P_H range suitable to their requirements. Thus tea will not grow on alkaline or even neutral soils, but requires soils of distinct acidity. Similarly, certain grains and legumes cannot be grown on acid soils. There are other crops which can be grown on soils of widely-varying reaction value.

Exchangeable or Replaceable Bases.—The properties of soils are markedly affected by the nature and amount of the exchangeable bases present in them. By exchangeable bases are generally meant the bases calcium, potassium, sodium, magnesium and ammonium which are absorbed by the clay complex of a soil and are easily exchanged or replaced by other bases, when the soil is treated with neutral salt solutions of the latter, *e.g.*, sodium chloride. In addition to these bases the clay complex has also a certain proportion of replaceable hydrogen. If the hydrogen is in excess of the bases, the soil is acid. If on the other hand the bases are in excess of the hydrogen, the soil is alkaline. When all the hydrogen of the clay complex is replaced by bases, the soil is said to be 'saturated'. When this is not so, as in most cases, the soil is said to be 'unsaturated'. The higher the degree of unsaturation, the more acid is the soil. The exchangeable base contents of a soil are expressed as percentages or more generally in milligram equivalents per 100 gm. of soil. A milligram equivalent of a base is its equivalent weight in milligrams. Thus if a soil is reported to have 10 mgm. equivalents of calcium in 100 gm. of the soil, it signifies a replaceable or exchangeable calcium content of 10×20 mgm. $= 200$ mgm. or 0·20 gm. in 100 gm. soil or a percentage of 0·20. Humid tropical soils, such as occur in Ceylon, have generally low exchangeable base contents. For a more complete account of exchangeable bases reference should be made to a paper by Eden [19] in *The Tea Quarterly*. Numerous methods have been adopted for the determination of exchangeable bases in soils, but the method found most convenient for use in this laboratory is that of Bray and Willhite in which ammonium acetate is used as the leaching agent.

Analysis of the Clay Fraction.—The analysis of the clay fraction of a soil is now regarded of the highest value, as it gives an insight into the properties of the soil and is of considerable significance from the standpoint of the genetic classification of soils. The determinations usually made are the silica, iron oxide and aluminium oxide contents. The silica/alumina molecular ratio of a soil makes possible its classification, on the basis of Martin & Doyne's [20] work, into one of three classes: laterite soils when the ratio is less than 1·33, lateritic soils when it is between 1·33 and 2, and non-lateritic soils when it is greater than 2. The method of analysis adopted in this laboratory is the ordinary sodium carbonate fusion method.

Acid Soluble Constituents.—The older soil analyses invariably included the determination of the percentages of silica, aluminium and iron oxides, potash and other bases as well as phosphoric acid and other constituents soluble in hydrochloric acid. While these data do occasionally furnish some clue to the failure of a crop on certain soils, and may afford indications of the reserves of plant nutrients in the soil, it is considered that, except for the potash and phosphoric acid contents, they do not furnish information commensurate with the time and labour involved in them. In the present series of studies, only in a few instances have the acid-soluble soil constituents, other than potash and phosphoric acid, been determined.

Available Potash and Phosphoric Acid.—These are empirical determinations of the soil potash and phosphoric acid soluble in one per cent. citric acid.

In addition to the above chemical determinations, a few physical determinations have been found useful in characterising soils. Of these the 'sticky point' moisture, which is the percentage of water a soil retains when after being well kneaded, it no longer sticks to the fingers or to a glass plate, is one of some importance.

In these investigations, soil physical determinations with the exception, occasionally, of the sticky point moisture have been omitted.

SOIL CLASSIFICATION

The ultimate end of all soil study being the classification of the soils of a country according to their agricultural potentialities and values, and the aim of modern soil work being the adoption of methods whereby this desired result is most likely to be achieved, it would be advantageous briefly to discuss the principles underlying various methods and schemes of soil classification, with a view to determining which of the latter might be adapted for local soils.

The age-old classification of soils on the basis of the texture of the surface soils, into clays, loams, sands, etc., while adequate for practical purposes in a limited area is unsuitable when it has to be applied to extensive soil regions, as soils very dissimilar in other respects would be grouped together. The classification of soils on a geological basis alone is again unsatisfactory, except in a limited area, for reasons already explained. A classification based solely on climate, without reference to geology, is also not complete, as has been previously indicated. Topography also influences soil development, even in regions of uniform geology and climate, mainly by its bearing on water movements, and must therefore be considered in any scheme of classification. Thus a well-drained soil would show very different characteristics to what it would exhibit under ill-drained conditions. This is well illustrated in the case of certain paddy soils. The only satisfactory method of classification is therefore one which takes account of the geological origin of the soil, its mode of formation and topography, the climatic conditions under which it was developed and the pedogenic processes to which it was subject.

These factors are best reflected in the soil profile which is therefore the natural unit of soil study and classification.

A number of schemes of soil classification has been proposed with the soil profile as the basis. It serves no useful purpose to discuss the merits of the various schemes; but it would be sufficient if such as are likely to have some bearing on any suggested scheme of classification of local soils are briefly outlined. Glinka [10] divided soils into two main classes: (1) soils in which external factors, *e.g.*, climate, predominantly affected their character; (2) soils in which the parent material affected their character. Of soils under the first class are the laterites and red earths, saline and alkaline soils. In the second class are the soils associated with limestone, *e.g.*, the red limestone soils (*terra rossa*), local examples of which are the Jaffna and Nalanda soils. Ramann [21] classified soils as humid and arid soils. Under the former class are included the laterite and red earth soils, and under the latter the saline and alkaline soils. Robinson [10] formulated a scheme of classification based on the character of the leaching processes. Under this system soils fall into three classes: (1) soils with complete leaching, *e.g.*, the red and yellow earths; (2) soils with impeded leaching, *e.g.*, the saline and alkaline soils and the grey soils, under which group the paddy soils as a whole may be assigned; (3) soils with incomplete leaching, characteristic samples of which are not found locally.

Any scheme of classification of local soils, even if it is tentative, must necessarily take into consideration drainage and rainfall conditions and geological factors. It should thus comprise within its whole the salient features of each of the schemes outlined above. Further discussion on this subject is deferred for the next paper.

Before concluding this brief account of the principles of soil classification, it might be well to refer to some terms used in soil survey work by American soil workers and adopted to some extent in Britain. The Americans use the term *soil association* or *family* to denote a group of soils possessing similar general characteristics, and which, though of similar geological origin, vary in profile details like colour and texture, but exhibit a uniform structure or consistency. A soil association consists of a number of *soil series* which in turn are subdivided into *soil types*. *A soil series* [13, 15] represents "a group of soils having the same character of profile, the same general conditions of drainage and relief, and usually a common or similar origin and mode of formation." The name of the series is taken from the region where the first number of that series was discovered, *e.g.*, Hanford series. In Ceylon all red soils derived from crystalline limestone would be classed under the Nalanda series, the best examples of these soils being found in the Nalanda district. A "soil which has got the same profile characteristics and the same texture throughout its occurrence is called a *soil type*." The name of the soil type is a combination of the series, name and the textural grade designation of the surface soil, *e.g.*, Hanford sandy loam or Nalanda medium loam. This terminology will be of value when detailed soil surveys are made. It would thus become necessary at a later stage of our work, once the recognition and characterisation of the main groups or associations of local soils, which is our first objective, has been accomplished.

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