STUDIES ON CEYLON SOILS

II.—GENERAL CHARACTERISTICS OF CEYLON SOILS SOME TYPICAL SOIL GROUPS OF THE ISLAND AND A TENTATIVE SCHEME OF CLASSIFICATION

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IN the previous paper of this series [1] some account was given of the principles underlying and the methods adopted in modern soil study and classification and their applicability in Ceylon. It was there indicated that the character of any particular soil is governed by one or more of the following factors: its geological origin, its topography and the climatic conditions to which it was subject. The part which each of these factors plays in the characterisation of the soil, and the ultimate result of their combined action, is reflected in the soil profile which is therefore the unit of present day soil study. In this article an attempt will be made to present a connected general account of the more important or wide-spread groups or series of Ceylon soils, based on the study of the soil profile. In these investigations only one or two typical soil profiles of each of the major groups of soils have been examined in detail, the object being more to determine broad distinctions between groups or series, rather than less marked differences between the individual types constituting each group. From the data thus obtained, some tentative classification of local soils is possible and a scheme is therefore suggested to serve as a working hypothesis. This scheme will doubtless have to be modified in the light of more intensive investigation, but as it offers a basis for future work, there would appear to be some justification for its publication. No attempt will be made to define the boundaries of these soil groups as has been done by Schokalsky [2] as this will require an exhaustive survey.

As however a preliminary to any systematic classification of the soils of a country is a knowledge of its geology, climatic conditions and topography, some account of each of these natural

features of Ceylon will be given, more particularly for the benefit of readers who do not possess a first-hand acquaintance with the Island.

TOPOGRAPHY

The pear-shaped Island of Ceylon, with an area of 25,332 square miles, is situated to the south-east of the Peninsula of India, between 5°·55 secs. and 9°·51 secs. north latitude and 70°·42 secs. and 81°·53 secs. east longitude. It is bordered by a coastal plain, very narrow along the southern margin of the Island but much wider on the western and eastern sides. The northern half of the Island is a great plain. From the coast, the land rises by fairly steep ascents to a central 'massif' forming the rugged highlands, culminating in the peak of Pidurutalagala, 8,290 ft. above sea level. This peak rises from a plain, called the third peneplain, 6,000 ft. above sea level. Between this latter and the coastal plain is a second peneplain 1,600 ft. above sea level. There are, it is reckoned, about 150 mountains varying from 3,000 to 7,200 ft. in altitude. Of these, Adam's Peak, 7,360 ft. high is the most famous from a religious and historical point of view. There are 16 rivers or streams most of which have their source in the hill country. Of these, the Mahaweli Ganga, 206 miles in length, is the largest, and the Kelani Ganga, 93 miles long, next in size and importance. The land bordering these rivers is quite fertile with the accumulation of alluvial silt and clay brought down from the hills.

CLIMATE

The climate of Ceylon, for the major part, is tropical. In the low-country the mean temperature is about 80°F. the range of variation being small. At the other extreme is Nuwara Eliya, at an elevation of over 6,000 ft., with an average temperature of 59·2°F. and a mean daily range of about 15°F. The hottest months on the west coast are March to May and on the east coast May to July.

The rainfall conditions vary a great deal over the Island, the annual range of rainfall being from 25 to over 300 inches. The greater part of rain falls during the two monsoons: the north-east from November to January and the south-west from May to September. In the intervening months inter-monsoon rains are prevalent. The south-west of the Island experiences the highest rainfall, varying from 80 to 300 inches per annum,

whilst the dry areas of the north, north-west and south-east have an average annual precipitation of less than 40 inches. The dry regions mainly benefit by the north-east monsoon. The driest months of the year are February and August.

Soil temperatures taken over a limited period at Peradeniya, in the mid-country, range from 74°F to 77·5°F. Temperatures in the low-country will be correspondingly higher and those up-country, lower.

GEOLOGY

The majority of the rocks of the Island are ancient crystalline rocks belonging to the Archean or Pre-Cambrian Age. They form an extension of the great area of crystalline rocks of South India. In the Jaffna Peninsula and the adjacent parts of the north of the Island these Archean rocks are covered by Miocene limestone. A narrow band of sedimentary rocks of Jurassic age occurs along the north-west coast at a place called Tabbowa. There are in addition littoral deposits of sandstone, raised coral reefs, submerged coastal flats, etc. and thick beds of recent alluvium occupying the valleys. These latter form the chief paddy-growing areas. Of importance from the soil standpoint are certain "plateau deposits" [3] belonging to the Pleistocene Age, which overlie the gneisses and older crystalline rocks. They are widely distributed over the low-country and vary in thickness up to 50 feet or more. They consist typically of two strata, the lower a "gravel" of quartz pebbles and iron concretions in a matrix of red clay, and the upper a red earth which is considered by Wayland to be a wind-borne deposit derived from the crystalline rocks. The gravel bed is not always present and it is not uncommon to find the red earth directly overlying the ancient rocks. The brick red colour is liable to be bleached from various causes to various shades of buff. According to this geologist, the red earth consists of sand grains and a finely divided material which is probably a mixture of kaolin or clay and iron oxides, with perhaps some hydrated aluminium oxides. The white sands (the cinnamon soils) of the Wesern Province and the light sandy soils of the North-Western Province are considered by Wayland to be derived directly from the red earth and to indicate swamp conditions in the past. Tennent [8], on the other hand, attributes the sandy deposits of the Batticaloa and Western coasts to the interaction of the sand-laden river waters and the currents skirting either coast.

Wayland [3] describes the geography of the red earth country as follows: "It is essentially low-lying with large domes generally less than 100 feet in altitude above sea level and 2 or 3 miles in length by, perhaps, 1½ in width. From the plain they resemble low ridges, but are best described as "turtle backs". They are covered with red earths, but the flats between them are of varying composition, and are younger than the red earth. The whole supports dense jungle or cultivation. The plateau beds are extremely pervious to water. All the larger red earth grains are composed mainly of quartz".

The ancient crystalline rocks are divided into the following important classes by Adams [4].

(1). The biotite gneisses which form a very large proportion of these rocks.

(2). Rocks of the Charnokite series of South India. These are a series of igneous rocks which range from highly acid hypersthene granites to norites and basic hornblende hypersthenites. They are characterised by a dark grey to black colour and the presence of hypersthene. They display a well marked foliation or banded structure.

(3). The granulites or leptynites. These are fine grained rocks of a white or pale-pink colour having a massive appearance. Garnets are often present in them. The rocks are largely devoid of the more basic minerals. They possess a foliation which is however not marked.

(4). Metamorphic rocks of sedimentary origin.

(a) Limestone. This mainly occurs in two well-defined bands known as the Badulla and Matale bands. The limestones range in composition from pure carbonate of lime to magnesium limestone or dolomite. The maximum width of a single band is a quarter of a mile.

(b) Khondalite or Sillimanite garnet rocks. These occur interbanded with biotite gneisses.

(c) Quartzites. These rocks are often interbedded with limestone.

(5). The Galle series. These are rocks closely related to the biotite gneisses and having some similarity to the Charnokites. They are of very limited extent and are characterised by

the presence of calcium minerals. Coates [4] includes this series with the Charnokites.

No account of the geology of Ceylon will be complete without some reference to the residual deposits of gneisses and other crystalline rocks, *viz.* laterite or *cabook* as it is known locally, and lateritic clays which mantle considerable areas of these rocks. Laterite chiefly occurs on the western coast from Negombo to Matara and for some distance inland where it is used for building purposes. It is a cellular, reddish, ferruginous clayey material, with mottlings of white hydrated aluminium oxides. The transitory state from gneiss to laterite is represented by the more clayey lateritic loams of the hill country. The red and reddish yellow colours of laterite are contributed by the oxides of iron and decomposed ferro-magnesian minerals, while the white or pale-yellowish colours are largely the result of the decomposition products of felspar. For more detailed information on the geology of Ceylon reference may be made to a publication by Adams [4] and a paper in the press by Coates [5].

CLIMATE, GEOLOGY AND TOPOGRAPHY IN RELATION TO LOCAL SOILS

The relative importance of each of the factors, climate, geology and topography in determining the character of the soils of the Island will now be discussed. Climate is undoubtedly the predominant characterising factor with the majority of our soils. The high temperatures and heavy precipitations alternating with periods of dry weather, which are experienced over a large part of the Island, are eminently favourable for chemical weathering and the development of laterite or lateritic soils where the nature of the parent rock material permits. In the process of laterisation the alkaline bases are leached out in combination with a part of the silica as soluble silicates, leaving a residual material considerably richer in the hydrate oxides of aluminium and iron than the original rock. The more advanced is the laterisation process, the higher is the proportion of sesquioxides (alumina and iron oxides) in the soil and more particularly, the clay complex. It is seldom, however, that pure laterite soils or soils derived solely from laterite are found in Ceylon, the great majority of the coloured soils being the lateritic type. This is all to the good, as laterite soils are generally infertile while those of the lateritic type are of fair agricultural value. Under other

conditions, as when the rainfall is deficient, or the drainage impeded, as in paddy soils, or the geological material unsuitable for laterisation as in the case of the Jaffna limestone, the tendency is for the weathering to be of the kaolinitic or ordinary clay type. Under these conditions the proportion of silica to sesquioxides in the clay complex is generally higher than in lateritic soils, the clay largely consisting of hydrated aluminium silicates, and the soils formed are of potentially greater agricultural value than the latter. Geology and topography in these cases play a more important part in soil characterisation than does climate.

Geological structure bears a close relationship to the character of local soils in extensive areas of the low-country, where the plateau gravels and red earth overlie the crystalline rocks. Where the red earth is of great or fair depth, the area is agriculturally fertile. Where, on the other hand, this strata is shallow and the gravel layer outcrops on the surface through erosion and other causes, or where it has been subjected to severe weathering, as is the case with the cinnamon soils, the soils are notoriously poor. Geology as a soil-characterising agent is best exemplified in the case of the Jaffna and other soils associated with limestone parent material. The uniform, free draining, deep red soils, similar to the *terra rossa* of the Mediterranean regions, to which these limestone rocks give rise, are quite independent of climatic influences. The alluvial deposits as are to be found along the valleys of rivers, or in low-lying paddy areas covered with the debris and fine wash from the surrounding hills, are other examples of soils bearing a close relationship to its geological origin. From their very nature, great variation in the actual composition of these soils is only to be expected, and the paddy soils of Ceylon furnish evidence of this.

The soils of the highlands and of the paddy areas furnish the best examples of the effect of topography on the character of local soils. In the former, severe erosion caused by the heavy and intense rainfall has depleted the soils, for most part, of the valuable surface soil, with its accumulation of humus, colloidal material and easily-available plant fertilising constituents. In the low-lying paddy areas, this wash from the hills is deposited. In these paddy soils the influence of water movement as governed by topography is seen to advantage. Typical paddy soils are generally, for the greater period of the year, either submerged under water or poorly drained, as far as ordinary arable soils go,

the water table being at or near the surface. As a result the soils are characteristically of the gley type, the lower layers being bluish grey to dark grey in colour and mottled brown by hydrated iron oxides. Under well-drained conditions, these soils make quite good arable loams. The up-country and the majority of the low-country soils are generally well drained.

From the standpoint of the soil scientist the crystalline rocks of Ceylon, whether gneissic or igneous, are of significance only in so far as they are geologically basic or acidic. The acidic members of either group like the granites or granulites, generally give rise to lighter coloured and textured soils, poor in lime, but likely to be rich in potash. The soils derived from the basic rocks like the norites, are darker red in colour and generally heavier in texture, while in regard to plant food constituents they tend to be rich in lime and poor in potash. The actual composition of the soil will however depend on the kind of weathering to which the rock from which it has been derived was subjected, and the subsequent pedogenic (soil-forming) processes it has undergone.

The potash contents of local soils are therefore variable, but, in the main, fair, with an average of about 0·2 per cent. except in the sandy deposits and light sandy soils which are markedly deficient in this constituent. Response of local crops to potassic manuring is not therefore generally marked, except on the latter types of soils. Calcium as free carbonate is conspicuous by its absence except in the soils of the Jaffna Peninsula and the neighbouring areas on the mainland, and in isolated areas where limestone outcrops on the surface. Soils overlying limestone, as at Nalanda, are however usually devoid of free lime. The intensive rainfall conditions would account for this deficiency. The total calcium content of local soils is generally poor, being on the average less than 0·2 per cent. Ceylon soils are very poor in replaceable bases, particularly calcium. This again is due largely to the heavy rainfall, the absence of free lime in most areas, and to the nature of the clay complex. The soils on the drier areas appear to have slightly higher replaceable base contents than those of the wetter regions. As a consequence, the soils of the wet zone generally show an acid reaction. Alkaline reactions are given by the limestone soils of the Jaffna type, and some of the dry zone soils. The paddy soils have a variable reaction.

There are no large deposits of phosphate minerals in Ceylon. The only phosphatic mineral found as an accessory constituent in very small quantities in the crystalline rocks, is apatite. As a consequence local soils are generally poor in phosphoric acid, though, except in the case of the sandy deposits, never without some reserve of this plant food constituent. The average may be regarded as less than 0·1 per cent. The other mineral constituents—iron, magnesium and manganese oxides which influence crop growth to some extent are found in more than adequate proportions in the majority of our soils, the exceptions being the light sandy soils.

To turn now to the organic matter contents of local soils in relation to the natural features discussed in the preceding sections. The climatic conditions over the greater part of the Island are such as to effect a speedy decomposition of the organic residues in soils where the drainage is satisfactory. Mohr [6] has found in Java that up to about a temperature of about 20°C. organic matter accumulates in the soil. Above this temperature "conditions are more favourable for the organic matter decomposing micro-organisms of the soil than for the higher plants which furnish the materials for these organisms to act upon, and the organic matter is destroyed as rapidly as it is supplied by plants." Local arable soils are therefore generally poor in organic matter, often containing less than 3 per cent. of this constituent, the exceptions being the soils of virgin forests, grassland areas (*patanas*) and fernlands (*damanas*) where amounts of this constituent up to 8 or 10 per cent. may be found. Under cooler conditions, and where the soil is constantly kept moist, as in the Nuwara Eliya District, accumulations of organic matter take the form of peaty deposit of from 2 to 5 feet depth in certain locations. Under anaerobic conditions, as in paddy soils, the organic matter contents are generally higher, and in small areas deposits of low-lying acid peat sometimes extending to 15 feet in depth are to be found. The best examples of such peaty deposits are to be found in the gemming areas of the Island.

The nitrogen content of local soils varies considerably, the average being about ·15 per cent. ranging from ·6 per cent. in the humus up-country soils, to ·01 per cent. in the sandy soils. The soils of the drier regions have generally lower nitrogen and organic matter contents than those of the wetter districts.

Taken as a whole the soils of the Island are by no means rich in mineral and organic plant food reserves. Numerous soils exist which are definitely poor in both respects. The low-lying paddy soils are generally richer in both mineral and organic plant food than the ordinary arable soils, but this is only to be expected as they contain the valuable eroded material of the neighbouring high lands. The soils of the Island being intrinsically poor, it may well be asked what the reason for the luxuriance of the local vegetation is. This is to be sought in the favourable light intensity and the high temperature and rainfall conditions generally experienced in Ceylon. As a consequence, photosynthetic activity is at an optimum. So also is bacterial activity, making quickly available the plant food reserves of the soil or what is added to it as organic matter. As Ramann[7] states: "Most tropical soils are deficient in plant nutrients and are in great need of manures. The foliage, which falls continually throughout the year, decays rapidly and the liberated plant nutrients circulating very rapidly suffice for the great luxuriance of the tropical forest. On the whole, the tropical forest works with a small capital of nutrients and a rapid turnover". Tennent [8] as early as 1860 writes in regard to local soils, not without reason, that "the soil notwithstanding its wonderful display of spontaneous vegetation, is not responsive to systematic cultivation and is but imperfectly adapted for maturing a constant succession of seed and cereal crops". Manuring of most local crops is generally required if continued good yields are to be obtained. With the view of the general poverty of tropical soils Vageler [9] is in agreement when he states that the "inexhaustible richness of tropical soils is but seldom found in Nature."

GENERAL CHARACTERISTICS OF THE MAJOR SOIL GROUPS OF CEYLON

The general characteristics of the more important soil groups or associations of the Island will now be considered. These groups, so far as our present knowledge goes, are as follows:

1. The laterite soils, lateritic soils, (red and yellow earths), and the non-lateritic red, yellowish red and brownish red loams. Red soils occur in both wet and dry regions.

2. Immature pale-brown loams of the humid mid-country and other immature soils.

3. The red and chocolate red soils associated with calcareous rocks, either sedimentary as in the case of the Jaffna soils or metamorphic, as in the case of the Nalanda group. These soils are comparable to the *terra rossa* of the Mediterranean regions.

4. The *patana* (grassland) and the *damana* (fernland) soils of the wet regions. These may be compared to the mountain peat world type.

5. The dry *patana* soils, which may be classed as tropical mountain steppes or savannahs.

6. Soils derived from "plateau" and alluvial deposits. These include the white cinnamon soils (dune soils), the pale-brown to red and chocolate-coloured sands and loams, and the gravelly soils.

7. Permanent and seasonal ground water soils. These include all the reddish brown to dark-grey paddy soils, the *talawas* (low-lying meadow soils), and the saline soils. The paddy soils could be suitably classed as *gley* soils.

8. The low-lying peat deposits associated with certain paddy and gemming areas.

9. Soils similar to the black cotton soils of India.

GROUP I

Laterite Soils.—These soils are derived directly from laterite, which is the residual product of the weathering mainly of basic and intermediate igneous and metamorphic rocks (gneisses) of the hot, moist low-country. Their constituents are mainly the sesquioxides of iron and aluminium, and crystalline quartz. The following analyses of local laterite samples by Bamber and Bruce will afford confirmation of this.

		I	II	III
Moisture & combined water per cent.		27·2	16·2	31·7
Iron oxide	,,	17·8	29·0	4·0
Alumina	,,	33·7	12·3	32·6
Insoluble matter	,,	22·0	42·7	33·0
Containing Alumina	,,	18·5	10·6	29·3
Silica	,,	3·5	30·0	3·7

Laterite is quarried to depths of as much as 30 to 40 feet and occasionally greater. The surface of these pits is generally mantled with concretionary gravel embedded in a matrix of fine clay of depth varying from 2 to 6 ft. The uppermost layer of laterite is hard and scoriaceous, but the hardness rapidly decreases with depth. The lowest horizon consists of very soft laterite containing large proportions of a yellowish-white clayey material (chiefly hydrated aluminium oxides) in the interstices. Laterite soils are chemically very poor, a typical soil examined showing only ·05 per cent. nitrogen, ·006 per cent. potash and ·001 per cent. phosphoric acid. They are acid in reaction. In certain areas the gravelly surface layer is altogether absent and the underlying soil, if so it can be termed, is hard and impervious to water. Root penetration is therefore impossible and crop failures often result. In other areas, however, the laterite has in turn undergone disintegration and given rise to porous gravelly soils of generally low fertility.

Lateritic and Non-Lateritic Red and Yellow Soils. (*Red and Yellow Earths and Loams*).—The great majority of the wet low and up-country soils of Ceylon may be classed as lateritic soils. They are deep, compact soils with colour variations, both within and between profiles, of red and pinkish red to reddish yellow and yellowish brown. Like laterite soils, they are usually formed from igneous and metamorphic rocks, mainly gneisses, *in situ*, but the laterisation process is only partial. The upper surface layers, especially of virgin soils, are brownish in colour due to the admixture of humus. There are, otherwise, no distinct horizons in these soils. The cultivated soils are generally poor in organic matter, but the nitrogen contents are variable. Potash contents vary but are generally fair, and phosphoric acid generally low. The soils are very poor in replaceable bases. In reaction they are acid. The soils vary in texture from sandy to clay loams and generally show increased clay or silt contents with depth. Analyses of the clay fractions for silica and alumina indicate that these red soils are, on Martin and Doyne's [11] criteria, either non-lateritic (red loams) with molecular ratios of silica to alumina greater than 2, or more generally lateritic (red earths) with ratios between 2 and 1·33. The former may be regarded as immature lateritic soils. These soils when well-cultivated are generally fertile, especially the red loams. They are sticky and plastic when wet, hard and

cloddy when dry. They drain fairly well because of the ferruginous and quartz gravel invariably associated with them. The gravel constitutes in certain areas a very high percentage of the soil mass, which is then of poor agricultural value. The up-country lateritic soils are similar to those of the low-country. Analyses do not reveal any appreciable differences between the red and yellowish soils except in regard to the iron oxide contents which appear to be higher in the clay fractions of the yellow soils. The colour variation is apparently due to differences in the nature of the hydrated ferric oxides in the soils. The pinkish soils have generally higher proportions of manganese oxide than the red and yellowish soils. These soils are suitable for a number of agricultural crops, particularly tea which requires acid soil conditions and rubber, but coconuts and other crops are also grown on them. For more detailed information on red soils reference may be made to a paper by Hardy [10] and to Vageler's book on tropical soils [9].

Dry Zone Red Soils.—The red to yellowish red soils of the dry zone also vary in texture from light sandy to heavy loams, and contains high proportions of gravel and quartz. They are mainly derived from the underlying rock but some are doubtless the residual red earth material of the plateau deposits. The uppermost horizon of these soils is of a red-brown colour due to the presence of humus, but the content of this material is generally lower than that of the wet zone red soils. The replaceable bases are of the same order, but the soil reaction is not so acid. The mineral plant food constituents vary, but generally appear to be slightly higher than in the soils of the wetter region. Owing to the lower rainfall their availability may however be lower. These soils drain well. They are generally non-lateritic in nature. They respond fairly well to cultivation with annual crops for the first two or three years, but subsequent yields are low. This has led to the development of a practice known as *chena* cultivation, in which crops are grown on recently felled and burnt jungle land for a year or two and then allowed to remain fallow for about six or seven years. At the end of this period the land is re-cultivated. Agricultural experiment has demonstrated that this wasteful practice can be advantageously replaced by a system of crop rotation. For the securing of continued good yields, however, manuring is essential.

GROUP II

THE IMMATURE LOAMS

In the mid-country at elevations up to 1,800 feet or thereabouts, fairly large extents of a pale-brown to pinkish-brown micaceous silty loam occur interspersed between the more mature red earths and loams. These loams are often very deep, porous, free-working soils, particularly devoid of concretionary material. They show no horizon development and are characterised by the presence throughout of thin flakes of brown mica. They appear to be formed *in situ* from micaceous gneisses. They are rather soapy to the feel when wet and do not dry hard. Analyses show them to be comparatively fair in mineral fertilising constituents but poor in organic matter. They are fairly fertile when well cultivated, though occasionally areas of poor agricultural value occur. They are obviously immature soils. Of not infrequent occurrence both up-country and low-country are soils, often of fair depth, consisting of recently-weathered rock. The strata of the latter are often clearly discernible in the soil profile. These 'rock brash' profiles are generally grey to pale-brown in colour and mottled white by decomposed felspar. They drain well, being loose and friable, and are deficient in clay, organic matter and available mineral constituents. They however break down to normal soil, comparatively quickly, under the intense weathering conditions of the tropics.

GROUP III

THE RED SOILS ASSOCIATED WITH LIMESTONE

In Ceylon these red soils are associated with two distinct geological formations. By far the more important of these are the soils of the Jaffna Peninsula and the north-west coast of the Island formed from sedimentary limestone, largely calcium carbonate. The soils vary in texture from light to heavy loams. The former, which are in the majority, are deep and well drained and generally of a brick red colour. The clay loams vary in colour from yellowish brown to deep chocolate, and are also fairly deep. These red soils are non-lateritic in nature. Free calcium carbonate is not frequently found in them, especially in the surface soils of very intensively cultivated areas, and when present is due to marine residues. Their exchangeable base contents are very high. The soils are alkaline in reaction and well supplied with phosphorous and lime. Nitrogen is low and so also the organic matter content. Potash is high in the

medium loams and very high in the clay loams. These soils are cultivated with a variety of crops under irrigation, and give good yields. Tobacco, vegetables and fruits are grown on the lighter soils; paddy, tobacco and other crops on the heavier loams.

The other group of limestone soils is that associated with and overlying the crystalline limestones, mainly dolomite, which occur in small areas in a number of districts. Of these areas the Nalanda-Dambulla district furnishes the most characteristic soil types. The soils are dark-red to chocolate, deep, free-working loams, showing no horizon delimitations. They are very well drained. Free carbonate is generally absent. The soils are similar to the red earths and loams, but are less compact, more friable, and not so sticky. They are well supplied with fertilising constituents particularly exchangeable bases, are generally slightly alkaline to neutral in reaction, and are quite fertile. They generally contain ferruginous concretions, which occasionally constitute a high proportion of the soil. With adequate rainfall or irrigation they can be made to grow a variety of crops.

GROUP IV

THE WET PATANAS AND DAMANA SOILS

The *patanas* or grasslands occur in fairly large extents in both very humid as well as moderately humid up-country districts. They have a very characteristic appearance. The vegetation of the wet patanas which occur at elevations of over 4,500 feet., consists mainly of coarse tufted grasses of which a common variety sometimes known as Gawara grass (*Chyrsopogon zeylanicus*). Bracken (*Pteris aquilina*) is common. Characteristic temperate species are also found. The only tree known to flourish in these patanas is *Rhododendron arboreum*. The rainfall and temperature conditions under which these patanas are developed are ideal for humus accumulation, the average temperature being about 60°F. and the rainfall about 98 inches fairly uniformly distributed over the year. The surface layer of the patanas extending to about 5 or 6 feet in depth occasionally, is a dark, friable soil containing a peat-like material. Its organic matter content is occasionally as high as 15 per cent. This layer is generally moist. Immediately underlying this is the B horizon of quartz and concretionary gravel in a dark-brown loamy matrix. The lowest horizon is a yellowish red compact

clay loam extending down to 15 feet and more. The wet patana soils are not well drained, owing to the heavy, compact sub-soil layers. The analytical examination of a characteristic wet patana profile shows that the soil horizons are distinctly acid. They contain fair quantities of phosphoric acid, but are poor in potash. The nitrogen content of the surface layer is high, but the B and C horizons are very poor in this constituent. The replaceable base contents are low. The results of clay analysis of soil samples from a patana profile at Kandapola, show them to be laterite soils, the silica/alumina ratios being about 0·8. It is likely, however, that soils of other similar profiles will be of the lateritic type. The patana soils make good tea soils when cultivated, but in the course of a few years the rich humus layer is entirely destroyed either through erosion or decomposition. In the depressions of the hills, the patanas give place to forest. For a full account of the patanas of Ceylon and of the theories of their origin, reference to Pearson's paper should be made [13].

Similar to the patanas of the up-country are the *damanas* or fernlands also known as *kekilla* lands of the moist low-country. Fernlands or bracken lands are also found to some extent in up-country and mid-country districts, where they are of good agricultural value. The ferns mainly found in the low-country *damanas* are *Gleichenia linearis* and *Nephrolepsis exaltata*. The grass *Themeda tremula* also occurs in the poorer areas. The dark-brown humus surface soil layer of these *damanas* is occasionally over a foot deep. The layer below this is a lateritic gravel, underlying which is a reddish gravelly loam containing boulders of undecomposed rock. The organic matter and nitrogen contents of the fernlands are not as high as those of the patanas, percentages of the former over 6 being rare. The soil layers of characteristic profiles examined show good reserves of potash, but poor phosphoric acid and replaceable base contents. The reaction is distinctly acid. The soils belong to the lateritic type and are amenable to cultivation with certain perennial crops, but are not suitable for annual crops.

GROUP V

THE DRY PATANAS

These patanas, comparable to mountain steppes or savannahs, extend to the east of the high mountain ranges between 2,000 to 4,500 feet altitude, over a large area which experiences

rainfall only during one season and a fairly long season of drought. They are the chief feature of the Uva Province. The average rainfall of the area is about 55 inches, most of which falls during the three months of the North-East Monsoon. The average temperature is about 70°F. with a fairly wide range of variation. The vegetation chiefly consists of coarse wiry grasses of the genera *Panicum*, *Imperata*, *Andropogon*, *Aristida*, etc., characteristic of the *savannahs* in other parts of the world. Several reasons have been assigned for the nature and origin of the Uva patanas. These are: shallow and poor soil, the outcropping of rock on the surface, lack of soil moisture, the incidence of rainfall and the long period of drought, patana fires, erosion and wind. It would suffice merely to state that each of these factors has perhaps influenced the formation of these steppes to some degree. Forest vegetation is largely confined, as in the case of the wet patanas, to the depressions and occasional crests of hills. Soil is absent over the greater part of these patanas, but areas of well-developed, deep soil, often of large extent, do occur. These areas are associated with bracken (*Pteris aquilina*). They have been found suitable for systematic cultivation, chiefly of tea and fruit. Where well developed, a dry patana soil profile exhibits a fairly high, humus-containing Ao horizon of varying depth, overlying a reddish-brown gravelly loam containing concretionary material and undecomposed boulders. The Ao horizon is absent in cultivated soils. The lower horizons are reddish and yellowish loams. Organic matter and nitrogen are fair in the A horizon but low in the others. All soil layers are poor in mineral constituents, slightly acid in reaction, and on the basis of the silica/alumina ratios of the clay fraction, lateritic in nature. The degree of laterisation of the patana soils is apparently connected with the rainfall conditions, being greater the higher the rainfall and more even its distribution. Craig and Halais [12] afford evidence in confirmation of this observation with Mauritius soils generally. The replaceable base contents of the dry patana soils, though low, are slightly higher than those of the wet patanas. The economic utilisation of any extent of patana country for agricultural or pastoral purposes will be dependent on a number of factors, but soil conditions would doubtless be the limiting factor in the greater part of the area

GROUP VI

SOILS DERIVED FROM THE "PLATEAU" AND ALLUVIAL DEPOSITS

The soils derived from the 'plateau gravels' to which reference has been made are as follows:

(a) The pale-brown to red and chocolate-coloured sandy and medium loams, and the grey-brown heavy loams.

(b) The cinnamon soils (dune soils).

(c) The gravelly soils.

(a). *The Light Sandy and Heavy Loams.*—The pale-brown to red and chocolate-coloured loams occur in the maritime regions of the Western and North-Western Provinces, and extend for some distance inland. They are mostly light sandy to medium free-draining loams, frequently of great depth. They show no very marked variation in profile characteristics, except that the surface layer is darker in colour owing to the addition of organic matter and of lighter texture. Underlying the main soil mass, often at great depths, is a clayey layer or the undecomposed rock. These soils are generally poor in fertilising constituents chiefly potash and phosphoric acid, and of slightly acid reaction. Exchangeable base contents are low. The soils are very suitable for coconuts, which are extensively cultivated in the districts they occur. Occasionally small extents of grey-brown heavy loams are found among the lighter soils. Both types of soils appear to be derived from the plateau gravel red earth plateau deposits, the finer particles of which have been in the case of the lighter soils eluviated to lower depths, leaving a quartz deposit occasionally coloured red by oxides of iron. Various types of soils of this series exist even in a comparatively small area. These soils are generally non-lateritic.

(b). *The Cinnamon Soils (Dune Soils).*—These are, according to Wayland, completely bleached red earth residual products, consisting of over 95 per cent. fine quartz and sand. The soils are considered to have been formed under swamp conditions. They are extremely poor in fertilising constituents. At varying depths extending to 6 or 8 feet, depending on the depth of the water-table, a blackish brown pan-like layer is observed. This contains accumulations of humus and sesquioxides leached down from the surface layers. The soils are acid in reaction.

In these respects these soils bear a close resemblance to the *podsols* of the humid temperate zones. Coconuts are grown on them, but require considerable additions of organic matter and potash to give good yields.

(c). *The Gravelly Soils.*—These soils are in reality the 'turtle backs' of the plateau gravels, from which the red earth surface stratum has been eroded. They are distributed in well defined directions between the light sandy loams described in a previous section. The gravel consists of either quartz or ferruginous concretions in a matrix of reddish clay. The percentage weight of gravel in the soil mass is very high, being in certain cases over 75 per cent. Root development on these soils is therefore poor and crop growth is affected accordingly.

The alluvial deposits, which are of more recent geological origin than the red earths, are generally confined to the more low-lying areas. They vary in depth and texture, all types of soils from sands to heavy loams being encountered. The latter are greyish brown in colour, fairly well supplied with organic and mineral plant food constituents, particularly the latter, and are often imperfectly drained. Deep drainage is therefore essential on these soils, which, if so treated, are rendered of high fertility.

GROUP VII

PERMANENT AND SEASONAL GROUND WATER SOILS

The permanent and seasonal ground water soils include the paddy soils of the Island and the *talawas* or low-lying meadow soils. In addition there are comparatively small areas of saline soils, confined mainly to heavy, low-lying paddy areas in the dry districts and the marshes adjoining the lagoons. Soil drainage is poor in these heavy soils, temperatures very high and rainfall low. Salt is therefore deposited as thin films on the soil surface during the dry weather through capillary action. The Hambantota and Puttalam districts and the Wanni furnish good examples of saline soils. The maximum total soluble salt content of one field on which paddy failed was 1·48 per cent. against an average of ·08 per cent. in well drained soils in the wet zone. The salt marsh areas are scattered over the Island and occasionally cover wide stretches of land. They are of no agricultural value.

The Paddy Soils.—The paddy soils of the Island generally occupy the flat low-country areas and the low-lying depressions between hills. Occasionally the crop is grown in terraced fields on the slopes of the hillside, but the proportion of land so cultivated is small. These soils are for the most part only seasonally under water, being irrigated artificially during the dry season in many cases. In a few areas, however, the soils are constantly ill-drained or water-logged. These are the *deniya* soils. Paddy soils range in texture from light sandy loams to heavy clays. In one case a clay content of over 76 per cent. was found. The average clay content of the paddy soils of the Island is however low and most of these soils will fall under the class of sandy to medium loams. Underlying the surface soil of 6 to 8 inches, which is the region of root development, is a sub-soil of much heavier texture than the surface layer. This is the result of years of puddling up to the depth of cultivation, with the object of retaining the soil water for as long a period as possible. Drainage in paddy soils is imperfect, but nevertheless existent. These soils during the cultivation of the crop are typical 'gley' soils. The surface soils vary from a dark-brown to grey-black colour, while the sub-soils are generally of a greyish to blackish tint, mottled and streaked reddish-brown by the hydrated iron oxides. The colour of the sub-soil is due to the anaerobic conditions obtaining therein.

Chemically, local paddy soils have, on the average, fair quantities of plant food constituents compared with those of other paddy-growing countries. Our soils are generally poor in potash and lime, and to a lesser extent in phosphoric acid, but contain fair quantities of nitrogen. They range in reaction from acid to slightly alkaline. Calcium carbonate in small amounts is very occasionally present. Physically, Ceylon paddy soils are lighter textured and of poorer water-holding capacity than those of other countries. For further information, reference may be made to Bruce's paper [14].

Under the sub-head of seasonal ground water soils may be classed the soils of the *talawas*, low-lying, park-like meadows of the semi-humid, hot low-country. These meadow lands occur between forest land, mainly in the country watered by the Mahaweli Ganga and other rivers flowing to the East. The soils are mainly loams and generally make good pastureland. Occasionally they are subjected to temporary water-logging and flooding.

GROUP VIII

LOW-LYING PEAT DEPOSITS

These low-lying peat deposits are associated with paddy soils or gemming areas characterised by the presence of excessive moisture. In some of the latter an acid peaty deposit of 1 to 20 feet overlies a gravel, termed *Illam*, in which gems are found. On the surface of the peat is an earth crust, 1 to 3 feet deep. Paddy is occasionally cultivated in these areas. An analysis of a sample of the peaty deposit showed it to contain, on air-dry material, 60 per cent. of organic matter, 28 per cent. ash and 12 per cent. moisture. The nitrogen content was 0·8 per cent., lime 1·7 per cent. and phosphoric acid 0·1 per cent. The peat was distinctly of the acid type, its reaction being 4·7.

Peaty deposits of much less depth also exist in low-lying paddy soils in certain districts like Matara in the Southern Province and Negombo in the Western Province. The peat in these cases is again of a distinctly acid nature and similar, chemically, to the gem field peats. These low-lying acid peats do not however occupy extensive areas.

GROUP IX

SOILS SIMILAR TO THE BLACK COTTON SOILS OF INDIA

These soils [15] are reported to be dark-grey to black silt loams of clodular structure, situated in the Mannar district near the village of Tunnekai and occupying an area of about 16 square miles. They are considered to be very suitable for cotton cultivation, being from 10 to 15 feet in depth. The soils are neutral to alkaline in reaction, rich in lime, fair in potash and poor in phosphoric acid. The nitrogen and humus contents are generally poor. Owing however to difficulty of access, no cotton-growing experiments were undertaken. The soils compare favourably with the black cotton soils of the Madras Presidency.

SCHEME OF CLASSIFICATION

Now that the characteristics of the major soil groups of Ceylon, as at present known, have been described, though somewhat sketchily, it would be quite pertinent and of some advantage to draw up some sort of scheme, based on recognised world systems of classification, into which local soil groups might be fitted. In the scheme suggested, following the method of

Robinson [16], consideration is first given to the question of drainage. The soils are divided into two large classes according as to whether the drainage is free or impeded. Each class is then subdivided into various geological soil groups and a further subdivision effected, based on climatic differences.

This scheme is only provisional and may require considerable modification. But it is attempted in the hope that it will lead to a wider and more intensive study of local soil groups and later, of soil types. Should any reader of this article know of any other important group of soils of the Island which has not been dealt with in this paper or referred to in the scheme, the writer would be pleased if such could be brought to his notice for investigation and future study. In the papers that follow the results of profile examinations of some of these soil groups will be detailed.

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TENTATIVE SCHEME OF CLASSIFICATION OF CEYLON SOILS

A. SOILS WITH FREE DRAINAGE

Under Humid Conditions	*Under Semi-Arid Conditions*
1. (a) Laterites (b) Lateritic soils (Red and yellowish earths) (c) Non-Lateritic soils (Red and reddish yellow loams of low and upcountry).	1. Red earth and loams of the dry zone.
2. Immature soils.	2. do do
3. Red and chocolate red soils derived from overlying crystalline calcareous rocks (*Terra rossa*) (*Nalanda* series).	3. Red soils derived from sedimentary limestone (Jaffna series).
4. Residual soil derived from 'Plateau Deposits'. (a) Reddish, pale-brown and grey sandy loams. (b) Cinnamon soils (Dune soils). (c) Gravelly soils.	4. (a) Red loams and gravels derived from 'Plateau Deposits' (b) Black cotton soils.
5. Soils derived from recent alluvium.	5. do do
6. Absent.	6. Dry *patanas* (tropical mountain steppes).

B. SOILS WITH IMPEDED DRAINAGE

1. Permanent and seasonal ground water soils: (a) Paddy soils (Gley soils). (b) Wet *patanas* (Mountain peats). (c) *Damanas* (Fernlands and bracken land). (d) Forest alluvial soils.	1. Permanent and seasonal ground water soils: (a) do (b) *Talawas* (c) Saline paddy soils and salt marshes.
2. Low-lying acid peats.	2. Absent.