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CEYLON SOILS

BY

S. N. U. FERNANDO

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CEYLON SOILS

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The Author...

BY

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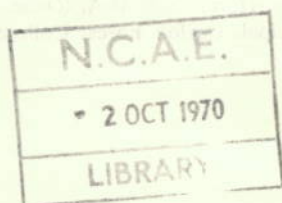
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The Author

S. Nihal U. Fernando, the author, is an Honours graduate of the Ceylon University and Oxford. Mr. Fernando spent four years at Oxford University, where his interest in soils was fostered. He is also a qualified Geologist. On his return from Oxford, Mr. Fernando joined the Forest Department as an Assistant Conservator of Forests. Presently he is serving in the Ceylon Forest College as its Principal.

A chapter of this book on "FERTILISERS AND THEIR USES", has already been published in the Ceylon Daily News Productivity Supplement in order to popularise the subject.

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His book gives a **new** classification of the soils of Ceylon, and for the **first time** the vegetation of the island is correctly correlated with the environment.



CONTENTS

Chapter I	Raw Soil Matter	...	1
Chapter II	The Soil Minerals, Soil Solution and Air	...	4
Chapter III	Soil Organic Matter	...	10
Chapter IV	Organisms of the Soil	...	14
Chapter V	How to describe a Soil	...	21
Chapter VI	Fertilisers and their uses	...	30
Chapter VII	Soil Erosion	...	37
Chapter VIII			
Chapter IX	Classifying Ceylon Soils	...	42
Chapter X	The Vegetation of Ceylon (Soils)	...	60
Chapter XI	Some adverse Conditions in the Soils	...	72
Chapter XII	Resume	...	74

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Chapter I

RAW SOIL MATTER

What are Soils?: Soils are the unconsolidated end products of the weathering of the rocks of the earth's outermost crust acted on by air, water, plants, animals, organisms, and organic matter, singly or in groups.

Thus, soils consist of a mineral fraction, an organic fraction, various solutions, air, and organisms.

Formation of raw soil material (parent material): The rocks of the outermost crust of the earth in Ceylon consist of, in order of importance, gneisses, charnockites, quartzites, limestones, schists, granites, clays, alluviums, and others. These rocks consist of various minerals with fixed compositions, form, hardness, and colour.

Weathering: All these rocks have to be broken down into smaller fragments, mineral constituents, or simpler substances, before soils can be formed from them. This process of breaking down of rocks is termed **weathering**. Some of the rocks of the earth's crust are unconsolidated and they resemble soils in many respects, as for example, clays. Some rocks are consolidated but are easily weathered to form raw soil materials, as for example sandstones. The majority of the rocks, however, are very hard and they have to be broken down with great difficulty. All rocks, whether soft or hard, are broken down by certain agents. These agents are physical, chemical, or both.

The agents of weathering: Physical agents do not produce new substances and they merely break the rocks to their mineral constituents or smaller fragments; that is, rocks merely crumble to pieces. On the other hand, chemical weathering produces new substances from the minerals of the crustal rocks; and for this water is a prerequisite. Therefore, weathering makes consolidated or unconsolidated rocks loose and friable, with or without the production of new substances.

PHYSICAL WEATHERING

The physical agents of weathering are many, and the most important ones operating in Ceylon are listed.

Alternate heating and cooling: In Ceylon, rocks get heated during the day and cool off in the night resulting in alternate expansion and contraction; these actions can tear rocks apart.

Alternate wetting and drying: This is another important weathering agent in Ceylon. Soft rocks such as clays absorb water during the rains and dry up later. When clays absorb water they expand and, on drying up, contract; and the rocks get fragmented in the process.

Sand blasts: Strong winds charged with sand particles act like bullets in systematically blasting away rocks. This type of weathering is quite common in the Dry Zone of Ceylon.

Moving water and waves: Moving water and waves, which are charged with sand particles, have the same action as winds (charged with sands) in eating rocks away. Water moving down streams running on the bedrocks corrode the underlying rocks breaking them down; this type of weathering is particularly prevalent in the upcountry. The action of waves is similar to that of moving water, and is familiar to all those who visit the seaside, particularly the Southwestern coast of Ceylon.

Frost: Frost occurs in Ceylon but it is not widespread. It occurs in elevations of over 6000 feet, especially during the dry month of February. When frost occurs, the water in the crevices of various rocks freezes, and in doing so expands and splits the rocks asunder. This type of weathering is only of very local occurrence in Ceylon.

CHEMICAL WEATHERING

The chief agents of chemical weathering of rocks in Ceylon are ordinary solution, hydration, hydrolysis, oxidation, reduction, and carbonation. Mere solution dissolves soluble minerals in rocks causing structural weaknesses, which results in eventual breakdown. Hydration is the addition of water molecules to compounds giving

hydrated substances. This results in expansion and consequent disintegration. Hydrolysis, carbonation, oxidation and reduction also dissolve certain substances in rocks causing structural weaknesses, as in the case of solution, thus breaking down these massive structures.

Some chemical agents have physical effects on rocks. For example, hydration causes expansion and disintegration of rocks. Therefore, the division of the agents of weathering, both chemical and physical, into watertight compartments, is not possible. Weathering agents act in groups and the net result of their actions give the raw material from which soils are formed: this raw material is called **parent material**. In Ceylon chemical agents are more dominant than physical ones. Besides, chemical weathering goes on at two to three times the corresponding rate in temperate zones; this is due to the high temperatures under which weathering occurs in Ceylon.

Chapter II

THE SOIL MINERALS, SOLUTIONS, AND AIR

SECTION I

Composition of unweathered rocks: The earths crust consists of over 100 elements, but of these only about fifteen form the bulk of the soil material; they are Carbon, Hydrogen, Oxygen, Phosphorus, Sulphur, Chlorine. Silica, Aluminium, Sodium, Iron, Manganese, Calcium, Magnesium, Potassium, and Boron. These elements occur profusely in the rocks of the earths crust, in air, and in water, in various combinations as minerals.

The average mineral composition of the earths crust is given,.

Table with 2 columns: Mineral Name and Percentage. Rows include Silicates of Sodium, Potassium, and Calcium (Feldspars) at 57.8%, Silicates of Iron and Magnesium at 16.0%, Quartz at 12.7%, Micas at 3.8%, Apatite at 0.5%, Other minerals (rare) at 9.1%, and Total at 100.0.

Weathering ability: The most abundant minerals of the earths crust which is the ultimate source of all soil material are the Silicates called Feldspars: they are a very important source of the elements Sodium, Potassium and Calcium. These minerals are easily weathered and are widely distributed in all soil forming rocks. Their weathering results in the smallest soil fractions; or the colloids and the clays, generally. The Ferromagnesium silicates do not weather so easily as the Feldspars, and they too give rise to smaller fractions (clays and colloids). Quartz is very resistant to weathering and it goes to form the skeleton of the soil which consists mainly of sand particles. The Micas are also resistant to weathering and they are mainly broken down physically to smaller particles. Micas are an important source of Potassium, a

scarce mineral. Apatite is the chief source of Phosphorus in soils, and it occurs only sparingly. Apatite too goes into solution relatively easily and is readily weathered.

Sands, silts and clays: The ultimate weathering of Quartz gives rise to sands and silts. On the other hand, the Silicates give the silts and the clays. Sands, silts, and clays are separated on the basis of size. Clays are obtained by chemical weathering alone, and they have different mineral compositions from the minerals of the parent rocks, unlike silts and sands. Clays are still complex silicates in which silica is combined variously with Aluminium and/or magnesium. The ratio of Silica to Alumina at this stage is 6.

Products: The products of weathering consist of disintegrated particles of the original rock, chemically changed minerals, and minerals in and out of solution. The raw soil matter thus derived, called parent material, consists of a solid fraction of fragmented or unfragmented Quartz, Iron minerals, Micas, Feldspars, and decomposed minerals, (especially clays) and others; and a soluble fraction of alkali salts, alkaline earths, acids and other inorganic substances existing in the rocks. There is a gaseous fraction too present between the interstices of the raw soil matter, consisting mainly of air, water vapour, Carbon dioxide and other gases.

It is from this weathered raw material that all soils are formed.

SECTION II

Formation of soils: After the raw matter is obtained by weathering, certain processes have to operate on the parent material before true soils are formed. The raw soil matter at this stage is chiefly disintegrated rock fragments and minerals, which are decomposed or undecomposed, in a friable form.

Soil forming processes: In Ceylon the chief soil forming processes that act on embryonic raw matter are one or more of the following three

Humus gives a dark brown colour to the topsoil. The brown colour becomes lighter as we go down the soil profile.

Humus in solution gives an acid reaction which has great solvent properties. The humus, as humic acid, may help in the leaching processes in the soil. This acid leaches the A horizon and it may deposit the leached substances in the B layers. Humus leached A horizons are very common in the various soils of temperate climates which give rise to Podzols.

Humus may be merely incorporated into such soils as laterites enhancing the acidity of these soils, even though laterites are formed under alkaline hydrolysis. These laterites are apparently fertile because of the rapid incorporation and use of humus nutrients.

Water-logging: The last type of soil forming process that could occur is water-logging. Sometimes this is called Gleyzation.

Often, a whole soil may get waterlogged. This inundation of the soil excludes air (Oxygen), and reducing conditions prevail in it.

All aerobic micro-organic activity ceases and unaerobic organisms take over. They decompose humus slowly resulting in the accumulation of organic matter. When the humus layer is over a foot it is called a **peat**. Peats consist of over forty percent of humus. Peats are very common in Colombo.

Sometimes only the lower regions of a soil gets waterlogged. Unaerobic conditions prevail only in this layer. Usually these lower subsoil layers have no organic matter. In these cases only the mineral raw soil material is reduced. For example, ferric iron is reduced to ferrous iron.; this gives a bluish-grey colour to the waterlogged horizon of the affected soil. Alluviums are frequently waterlogged in Ceylon.

Waterlogging degrades good soils. The waterlogging may be due to an impervious subsoil horizon that does not allow water to percolate, or it may be caused by topographic features; for example, in the Upcountry bogs waterlogging is the result of the location of the soil in hollows with impervious bedrock.

Incidence of Soil forming processes: Of the three soil forming processes waterlogging is only of very limited occurrence in Ceylon. Leaching and Incorporation of Humus are the two main agents that act on weathered materials to form Ceylon soils. Further, in most soil forming processes Leaching is primary and Incorporation of Humus is secondary (e.g. Lateritic and Red earths.) In some types all three soil forming processes may go on at the same time.

As a result of these three processes true soils are formed consisting of an organic, a mineral and a living micro-organic fraction, with water and air. The mineral fraction, the soil solution and air, have already been described; the organic fraction and organisms remain.

In Ceylon one of the most dominant soil forming processes is desilication which results in Lateritic types, leaving iron and aluminium immobile. True Podzols formed by acid leaching under temperate type climates, with resultant mobilisation of iron and aluminium, are absent in Ceylon. Therefore, it is incorrect to distinguish Podzolic soils in Ceylon as all past classifications have attempted to do (Panabokke and Joachim). **The new classification of Ceylon soils by the author is given later. (It includes a new classification of the natural vegetation which is also correlated to the different soil types of the Island.)**

Panabokke and Moorman have even gone to the extent of discovering Podzols interspersed with Laterites in Ceylon. This is very unlikely; it shows more of a lack of elementary knowledge on the fundamental processes of podzolisation (deferralization) and laterisation (desilication), than the discovery in Ceylon of anything so novel as podzolic soils which are so common in temperate climates. Obviously, they have discovered a mare's nest.

SOIL ORGANIC MATTER

Plants continually shed their leaves, twigs, and other vegetable parts, on to the soil. These undecomposed vegetable additions to the soil are called **litter**. This is really a green manure. The plants themselves may die and increase the amount of litter. Besides litter, decomposing animal remains are also continually being added on to these raw soils. The total organic matter content of the soil consists of decomposed and undecomposed litter, and decayed animal remains. When this organic matter is decomposed to such a degree that its individual constituents are indistinguishable then it is termed **humus**. Humus is a dark brown amorphous substance. The brown colour of humus is especially noticeable when it is wet.

The nature of humus will depend on the chemical composition of the organic matter from which it is derived, on the environment in which it is formed, on the organisms acting on it, and on the stage of decomposition.

Humus is in essence a mixture of carbohydrates, proteins, lignins, cellulose, fats, oils, waxes, and their derivatives. These compounds serve as food for a host of micro-organisms living in the soil (example bacteria, fungi and earthworms), and in the process they are broken down into simpler assimilable substances which serve as a source of nutrients to plants. Therefore, the soil organic matter is the seat of the very important process of nutrient mobilisation especially of scarce elements such as Nitrogen, Phosphorus and Potassium.

Humus may be intimately mixed with the mineral matter of the soil when it is called a **Mull**, or it may be relatively unincorporated sitting on top of the mineral layer; then it is called a **Mor**. Where organic matter is incorporated into the soils it is accompanied by intense biological activity, and the soils take on a crumbly appearance very much like bread crumbs. This makes

the soils porous and well aerated, and since they are enriched with nutrients from decomposed humus they are very fertile. On the other hand, where humus is unincorporated the soils are very compact with little biological activity in them. Since the humus is undecomposed nutrients remain fixed in it and are not released. Though these soils have a large capital of potential food in the humus they are still infertile since the nutrients are fixed and unavailable. Humus remains unincorporated in soils subject to burning in Ceylon, and they give rise to grasslands.

In highly leached soils most nutrients are washed off. In these cases it is the humus that maintains the fertility of them by the fixing and continual rotation of nutrient element between itself and the plants. Humus plays a leading role in maintaining the fertility of highly leached soils; for example laterites.

Humus is very spongy and is able to absorb and retain enormous quantities of water in its body — sometimes over 100 percent of its bodyweight. This property of humus is invaluable in areas where there is a scarcity of water as in the Dry Zone.

Humus is a buffering agent like clays, and it keeps the soil reaction (ph) constant without change.

Humus makes heavy soils light and more porous. Clays are made lighter and better for plant growth by the addition of humus. The effect of adding humus to any soil is comparable to adding yeast to flour. It makes it porous and light thus improving the soil aeration.

Humus is mostly made of the particles of the smallest physical size possible called colloids. The colloidal humus particles are negatively charged. Therefore, they are able to absorb and retain positive particles such as Potassium, Ammonium, Calcium Magnesium, and others, which would otherwise get washed off in leaching water and become scarce thus reducing the nutrient capital of that soil. The elements that are most mobile in the soil are Chloride, Sulphate, Nitrates, Calcium, Sodium, Magnesium, Potassium, Silica, Iron and Aluminium. Of these, the positive ions are lost if they are not fixed by the colloidal fraction in soils, of which humus is a most important constituent.

Humus is a bad conductor of heat and it insulates soils against extremes of temperatures. (and also fluctuations.)

Effect of burning soils: When soils are burned it is the humus fraction that is chiefly destroyed. Besides a great amount of carbon black is formed which can absorb large quantities of heat; this may render the soil unsuitable for regeneration. On the other hand, the warmer soils may enhance germination of seed. Another drastic effect of burning is that the soil immediately loses its crumbly and porous structure degrading the soil.

Further, the positive particles adhering to the colloidal humus fractions are immediately released. The result is that the soil is suddenly enriched with alkali particles such as Potassium, Calcium, and Sodium, which render it alkaline. This may inhibit the growth of many plants. Burning is recommended in very acid soils because the alkaline products released will reduce the acidity and make it less unfavourable for plant growth.

The organic matter content of Ceylon Soils: The organic matter content of Ceylon soils is very low (around two percent usually) when compared with temperate types (which generally have 10 percent).

Dry and Arid Zone soils, which cover over two-thirds of Ceylon, have one to three percent of humus. Certain coastal sands in these zones may have less than one percent in all.

The Wet Zone (both Lowcountry and Montane) which cover the rest of Ceylon, contain from three to fifteen percent on the average, but pockets of Peat occur here and there where the value exceeds fifteen percent; the Wet (patana) grasslands contain 15 percent of humus and all the Peaty soils from 15 to 50 percent. The amount of organic matter increases with altitude in Ceylon (since low temperatures inhibit decomposition).

Generally peats contain over 15 percent of humus, whereas laterites contain much less; but, in laterites the cycle of breakdown of humus, its subsequent absorption by plants, and its ultimate release back again to the soil on their death, goes on at a much faster rate than in peats, with a result that nutrients are better circulated and utilised in them than in the latter. This is the

reason why laterites support such giant forests though their nutrient capital is much less than in peats; that is, the conversion of litter into humus is very rapid and it keeps pace with the supply from above from the plants themselves.

High temperatures favour the decomposition of organic matter while low values inhibit it. This is because micro-organic activity is accelerated at high temperatures (up to a maximum.) Naturally, Dry and Arid Zone soils have little humus. On the other hand the Upcountry Wet Zone enjoying lower temperatures has more humus content.

Waterlogging has a similar effect to low temperatures in retarding the breakdown of humus (resulting in the formation of peat bogs). Peat bogs are formed in permanently waterlogged areas even though the place may be enjoying high temperatures. In fact, peats can be formed in any temperature regime provided the area is permanently inundated. Hence, peats are common in the cool Upcountry too.

ORGANISMS OF THE SOIL

The number of organisms in most soils range to many millions per gram ordinarily. In very inactive soils, as for example sea sand, there may be only a few thousands per gram. These organisms are found in the interstitial spaces, burrows and solutions, of the soil.

Decomposition of organic matter: The chief function of the soil organisms is to decompose organic matter and to release the nutrient elements locked up in them to the plants in simpler forms. Some of these micro-organisms, as for example certain bacteria, can absorb atmospheric nitrogen and are able to release it to the plant in assimilable form on death. Some fungi can live in the roots of higher plants and they are able to absorb nitrogenous compounds from the soil, which they release to the host on death: in its turn it absorbs carbohydrates from the host plant; this relationship is named **symbiosis**; the association of the fungi in the roots of higher plants is called **Mycorrhiza**.

Some micro-organisms absorb mineral nutrients and they store it in their bodies in various forms which are released back again to the soil on death. In this way they keep the nutrient elements in the upper layers of the soil without loss by leaching. This continual rotation of plant nutrient between the micro-organism and the soil helps to conserve these elements; otherwise, they would get leached during rains.

Some of the organisms are able to mechanically reduce soil matter to smaller more reactive sizes and colloids. This is particularly true of the larger organisms; example, earthworms.

Soil organisms are also mainly responsible for **crumb structures**. They are able to aggregate soil particles into spongy crumbs thus increasing the pore spaces (porosity); the soil structure is thereby improved. Others bore tunnels and aerate the soil: e.g.; earthworms. Larger soil organisms (e.g. Moles, rats,) facilitate the decay of organic matter by burying it.

Some soil organisms hasten the germination of seeds by burying them or by breaking dormancy (by passing the seeds through their guts or by other means). Larger organisms also help in the dispersal of seeds.

Certain micro-organisms are, on the other hand, destructive. Some of them induce toxicity in soils. Others denitrify nitrogenous compounds releasing valuable and scarce nitrogen back again to the atmosphere under unaerobic conditions. The entire population of organisms in the soil consists of bacteria, fungi, algae, protozoa, actinomycetes, nematodes, earthworms, insects, rodents, moles, shrews, porcupines, rabbits, polecats, anteaters and other earth inhabiting plants and animals. These organisms usually require good aeration, water, suitable temperatures, food, satisfactory soil reactions, and the absence of toxins for their survival and optimum activity.

Bacteria: The most important group of soil organisms are the bacteria. Some require air for their activity, others do not. Those that require air to live are more numerous than those that do not. That is why decomposition is slow in waterlogged soil—because air is excluded. Bacteria are able to feed on organic and inorganic matter. The usual food of bacteria are proteins, carbohydrates, fats, waxes, cellulose, ammonium nitrates, nitrites, and so on.

The role of bacteria in decomposing nitrogenous compounds is familiar to all. Bacteria by the name of *Bacillus mycoides*, *B. putrificus*, and *B. vulgare*, break down proteins to ammonium salts. These ammonium compounds are oxidised to nitrites by *Bacillus nitrosomonas*. The nitrite is turned into assimilable nitrate compounds by *B. nitrobacter*. These nitrate compounds are readily snapped up by plants. Plants generally absorb nitrogen in the form of nitrates though sometimes they are able to absorb ammonia directly. Therefore, bacteria play a vital role in the mobilisation of nitrogen in the soil. Otherwise this nitrogen would be unavailable to the plants or they would be lost in leaching. It must be remembered that the bulk of the nitrogenous compounds in the soil is contained in the organic matter or humus. Hence, if humus is lost the soil gets depleted of nitrogenous salts as a consequence. It is the bacteria, then, that are mainly

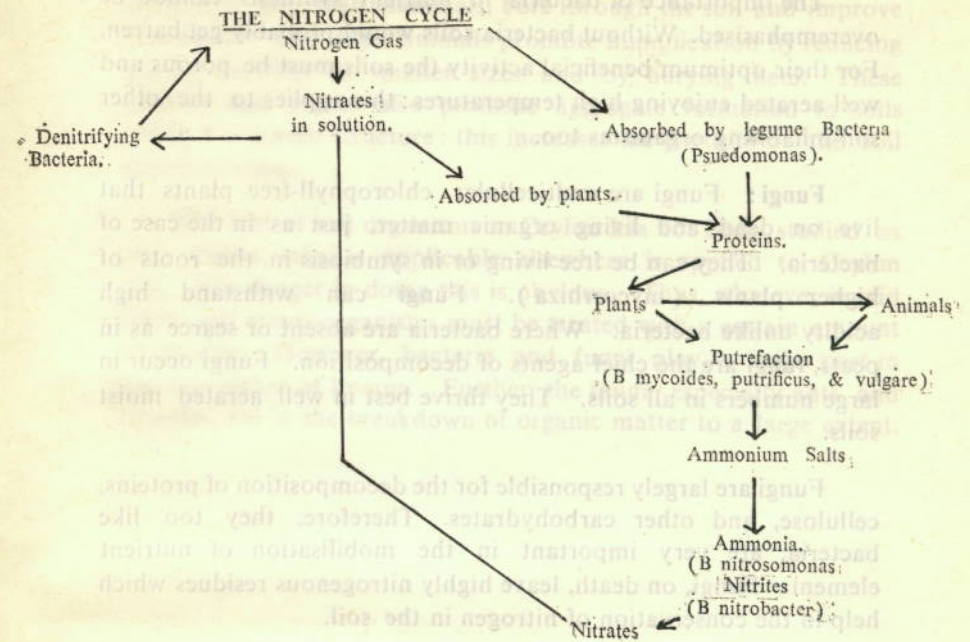
responsible for keeping nitrogen in circulation in the soil. For this nitrification the soil must be well aerated with an ample supply of water, coupled with high temperatures.

Bacteria play a similar role in the decomposition of carbohydrates; namely sugar, starches, cellulose, and hemicellulose. Cellulose, for instance, occurs in bulk in the soil and a bacteria named *B cellulomonas* breaks it down. Without this bacterial activity there would be a large accumulation of organic matter in soils if they are not leached out forming peats.

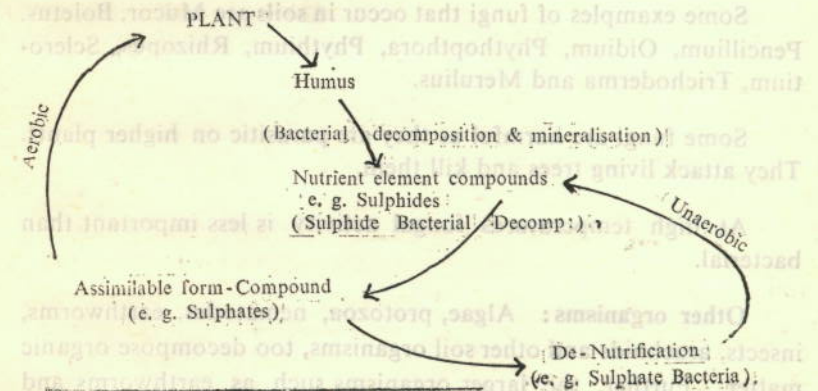
Two other bacteria decompose sulphur and iron compounds in the soil. Certain sulphur bacteria can decompose sulphides to the available form of sulphates, which can then be absorbed by plants. Similarly, ferrous iron is made available to plants by conversion to ferric iron bacteria.

Certain bacteria can fix atmospheric nitrogen directly into their bodies, which they release later to the soil, on death. These are termed **nitrogen fixing bacteria**. They are some of the few organisms that can fix atmospheric nitrogen. Higher plants are unable to do this, and they have to depend on soil salts for their nitrogen. The reason why plants cannot absorb atmospheric nitrogen directly is that this gas is very inert and non-reactive. Some of these nitrogen fixing bacteria are free living, as for example aerobic *B azotobacter* and anaerobic *B clostridium*. Others, namely *B rhizobium*, inhabit the roots of higher plants fixing nitrogen and passing it on to the host plant in exchange for other foods; these are the famous nodule bacteria. They are particularly common in the roots of legumes. The 'fair exchange, no robbery' relationship between the bacteria and the host is called **symbiosis**.

Just as much as there are bacteria that can fix atmospheric nitrogen, there are others that can do the reverse; i. e. break down nitrates and other nitrogen salts back to free nitrogen gas. These are called **denitrifying bacteria**. These bacteria require anaerobic conditions for their activity. This is the reason, among others, that it is very necessary to have soils porous and well aerated. There are also anaerobic Sulphate decomposing bacteria that reduce the compounds to unassimilable Sulphides; this process is very similar to denitrification.



General NUTRIENT ELEMENT CYCLES
(example Sulphur)



The importance of bacteria in nutrient synthesis cannot be overemphasised. Without bacteria soils would probably get barren. For their optimum beneficial activity the soils must be porous and well aerated enjoying high temperatures: this applies to the other soil inhabiting organisms too.

Fungi: Fungi are multicellular, chlorophyll-free plants that live on dead and living organic matter, just as in the case of bacteria. They can be free living or in symbiosis in the roots of higher plants (mycorrhiza). Fungi can withstand high acidity unlike bacteria. Where bacteria are absent or scarce as in peats, fungi are the chief agents of decomposition. Fungi occur in large numbers in all soils. They thrive best in well aerated moist soils.

Fungi are largely responsible for the decomposition of proteins, cellulose, and other carbohydrates. Therefore, they too like bacteria, are very important in the mobilisation of nutrient elements. Fungi, on death, leave highly nitrogenous residues which help in the conservation of nitrogen in the soil.

Some fungi are even able to fix atmospheric nitrogen, in similar manner to *Bacillus Rhizobium*.

Fungi, being plants, release carbon dioxide gas in the soil which makes insoluble phosphate compounds more soluble and thus assimilable.

Some examples of fungi that occur in soils are *Mucor*, *Boletus*, *Penicillium*, *Oidium*, *Phytophthora*, *Phythium*, *Rhizopus*, *Sclerotium*, *Trichoderma* and *Merulius*.

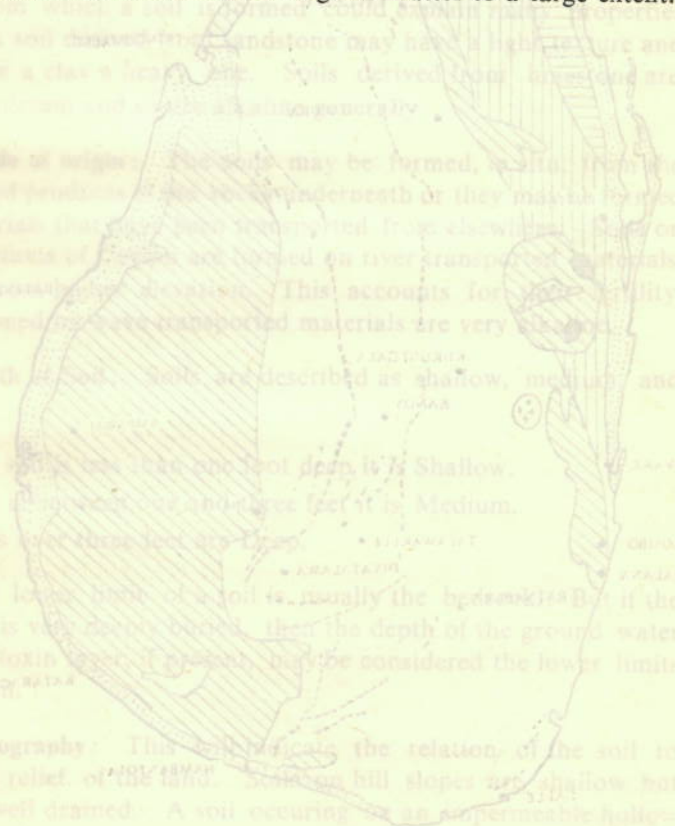
Some fungi are harmful as they are parasitic on higher plants. They attack living trees and kill them.

At high temperatures fungal activity is less important than bacterial.

Other organisms: Algae, protozoa, nematodes, earthworms, insects, arachnids and other soil organisms, too decompose organic matter. Further, the larger organisms such as earthworms and

nematodes and small mammals, bore through the soil and improve its aeration. The larger animals promote humification by reducing humus particles to smaller sizes and by burying them. These animals and plants also promote aggregate formation in soils giving it a crumb structure: this increases the porosity of the soil manifold times.

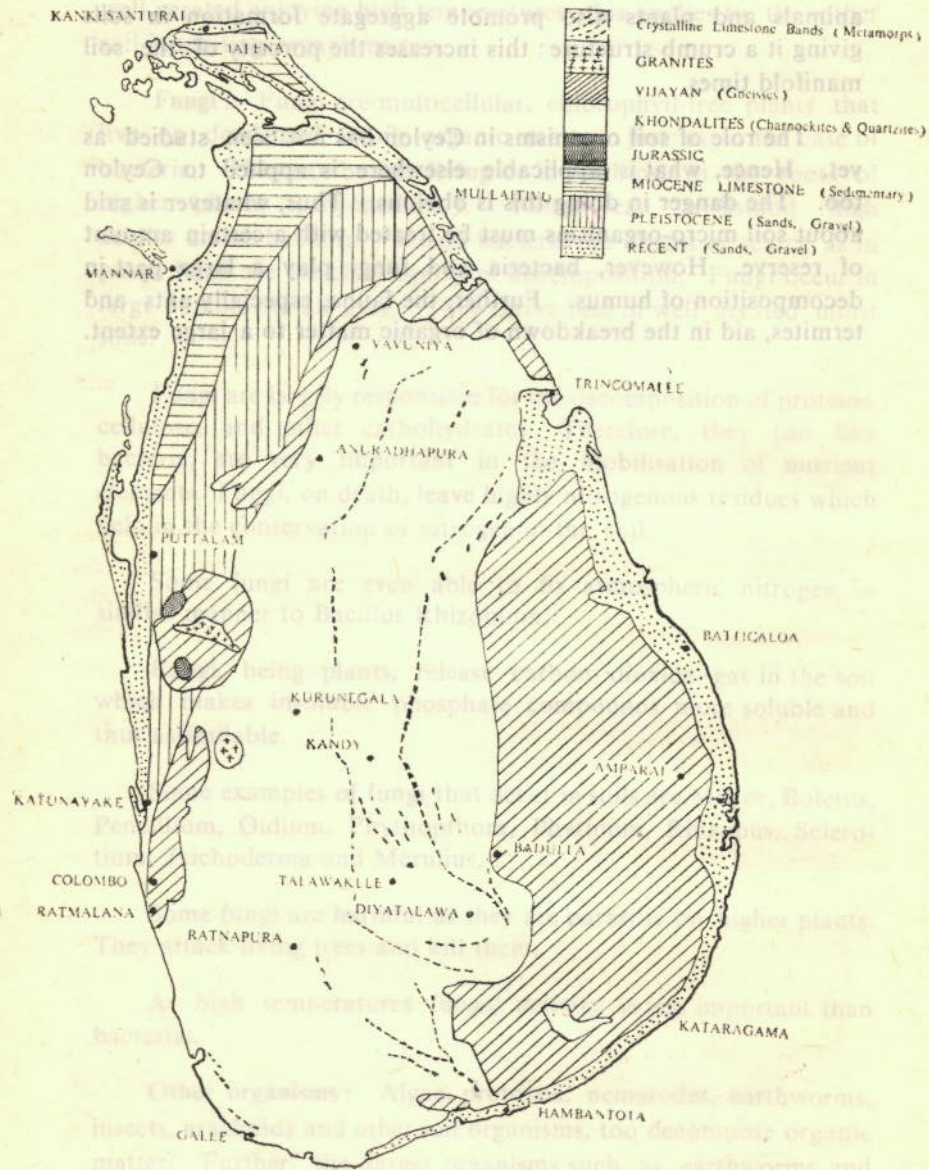
The role of soil organisms in Ceylon has not been studied as yet. Hence, what is applicable elsewhere is applied to Ceylon too. The danger in doing this is obvious. Thus, whatever is said about soil micro-organisms must be treated with a certain amount of reserve. However, bacteria and fungi play a large part in decomposition of humus. Further, the fauna, especially ants and termites, aid in the breakdown of organic matter to a large extent.



Topography: This indicates the relation of the soil to the local relief of the land. In hill slopes are shallow but usually well drained. A soil occurring on an impermeable hollow may be waterlogged.

PROVISIONAL GEOLOGY OF CEYLON

Incorporating works of
L. J. D. Fernando and P. G. Cooray



Chapter V

HOW TO DESCRIBE A SOIL

The following are the chief characters that are used in the description of all soils. As many of them as are evident must be described.

The Geology: In Ceylon the average depth to which geological rocks are buried is thirty feet. In the plains they are buried deeper than in the hills. A study of the geological rocks from which a soil is formed could explain many properties of it. A soil derived from sandstone may have a light texture and that from a clay a heavy one. Soils derived from limestone are rich in calcium and so are alkaline generally.

Mode of origin: The soils may be formed, in situ, from the weathered products of the rocks underneath or they may be formed on materials that have been transported from elsewhere. Soils on the alluviums of Ceylon are formed on river transported materials, eroded from higher elevation. This accounts for their fertility. Soils formed on wave transported materials are very alkaline.

Depth of Soil: Soils are described as shallow, medium, and deep.

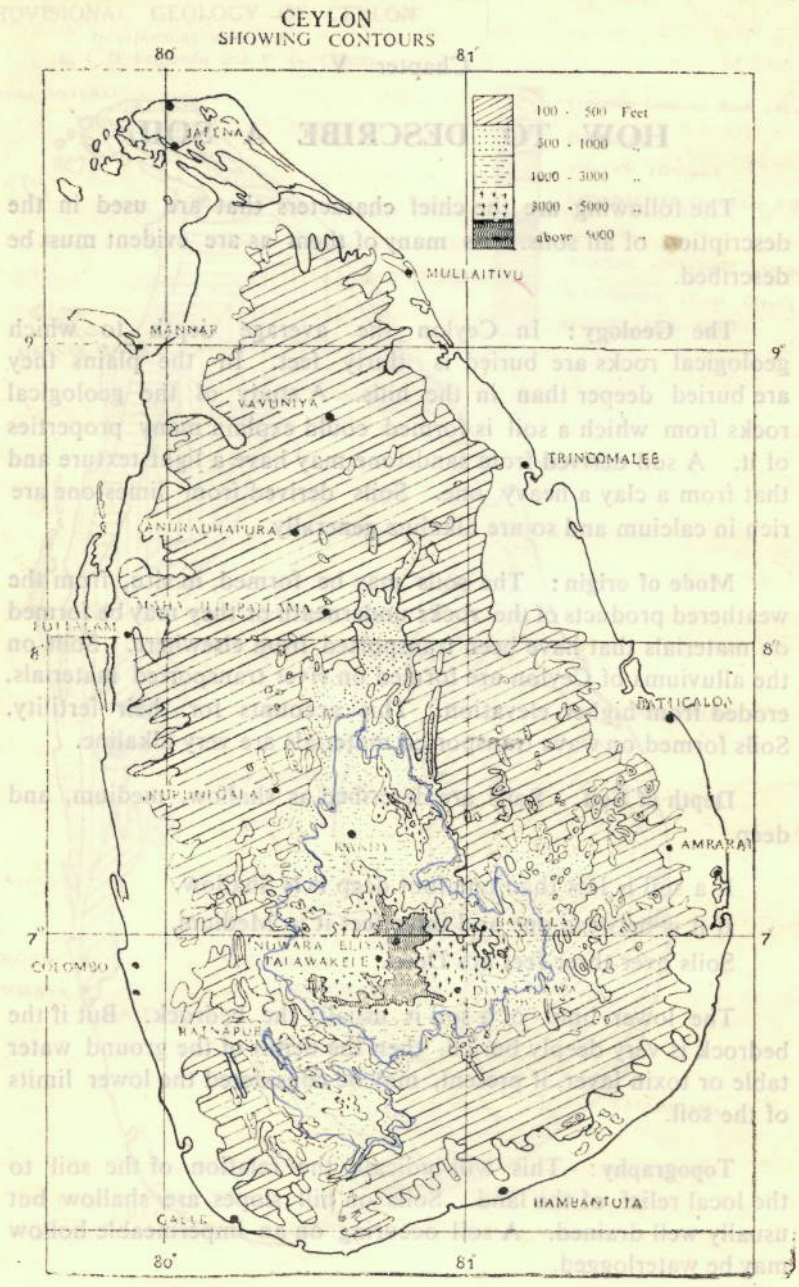
If a soil is less than one foot deep it is Shallow.

If it is between one and three feet it is Medium.

Soils over three feet are Deep.

The lower limit of a soil is usually the bedrock. But if the bedrock is very deeply buried, then the depth of the ground water table or toxin layer, if present, may be considered the lower limits of the soil.

Topography: This will indicate the relation of the soil to the local relief of the land. Soils on hill slopes are shallow but usually well drained. A soil occurring on an impermeable hollow may be waterlogged.



Climate : The climate has an overriding effect on the formation of the different types of soils found in Ceylon. The components of the climate that operate in Ceylon are the temperature and rainfall.

In the case of rainfall it is important to know not only the total annual amount, but also its distribution, periodicity, intensity and the like. Similarly, the average annual temperature must be known together with its seasonal and daily variations. It must be mentioned that extremes of temperature and rainfall are more important to know than the mean; frosts, excessively high temperatures, droughts, are examples.

The Soil profile : This is what one observes on a vertical cutting of a soil. Usually one describes the profile by cutting soil pits; but in Ceylon the depth of the earth is great so that a pit will show only the superficial layers. Therefore, to describe the whole profile, roadside cuttings, embankments and the like must be studied together with the pits. If this is not possible every effort must be made to describe up to the first seven feet, or the ground water table. An examination of a profile will indicate the type of soil forming processes that are operative. Important points to note are the depth of the various horizons together with their boundaries.

Boundaries of horizons maybe **Sharp** if it is less than one inch thick, **Clear** if it is between one and two inches, and **Merging** if over two inches thick.

Soil Colour : Various colours indicate different properties of soils. The commonest colours in Ceylon are the reds and the yellows. These two colours are usually given by the oxide of ferric iron. A brown colour is caused by the presence of incorporated humus. Black colours are invariably peats. Bluish-grey colours indicate that the soil is waterlogged. Colourless horizons demonstrate the abundance of silica. Limestone and certain clays give a white colour to the soil. Mottled Red-Yellow is certainly hydrated ferric oxide, while uniform red is non-hydrated.

Soil texture: The texture indicates the amount of sand, silt, and clays in a soil. The texture ranges from sands to clays. Sands, silts and clays are separated on the basis of size.

Stones, boulders are greater than	2	m. m. in diameter.
Coarse sand is	...	2 m. m. to 0.2 m. m.
Fine sand is	...	0.2 m. m. to 0.02 m. m.
Silt is	...	0.02 m. m. to 0.002 m. m.
Clays are less than	...	0.002 m. m. in diameter.

There are some useful methods of distinguishing sands, silts and clays. If the soil is sticky it is a **clay**; if it is silky it is a **silt**; and if it is gritty it is a **sand**. If the soil is not gritty, silky, or sticky it is a **loam**.

Sandy soils are light and they allow water to percolate while clays are heavy and they absorb water till they get waterlogged.

An equal mixture of sand, silt, and clay is termed a loam. Sands give the skeleton of the soil whereas the clays are the seat of all the chemical activity. A pure sand, therefore, is nonreactive for it has no clay.

To determine the amount of sand, silt, and clay in a soil sample, put it in a graduated jar and shake it up with an ample amount of water; then allow the mixture to settle for one day. The sand being the heaviest it will settle quickly with the silt over it. The clay being the lightest it will settle over the silt after one day. If there is humus it will float on top and form a scum.

Secondary chemicals and minerals: It maybe possible to identify these and to give their nature, amount, and disposition.

Soil Structure: Sands, silts, and clays, have a **Simple** structure. But, if certain substances such as humus are added, there is a tendency for individual particles to aggregate giving a crumb structure to the soil. Such **Aggregate** structures are better than simple ones. The formation of crumb structures can be compared to the raising of bread from dough; that is, the porosity is increased tremendously.

Other structures: Sometimes certain soils show laminations, cubes, columns, and prisms.

Soil organic matter: Ceylon soils are generally poor in organic matter, the average being around two percent. (temperate soils have 10%). It must also be observed whether the humus is incorporated or not. Humus is generally indicated by a brown (incorporated) or black (unincorporated) colour. The depth to which humus is found must also be noted.

Consistency: Many types of consistencies are recognised.

Loose; if the soil particles easily run through the fingers,

Compacted; if the soil digs clean and well.

Indurated; if an auger is used and it grinds when screwed in.

Friable; if the auger comes up loosely packed.

Tenacious; if the auger sucks and comes up.

Soil water: The degree of wetness of a soil can be found out by a simple test.

Dry soils: The soil is **Dry** if its colour changes on wetting.

Wet Soil: The soil is **Wet** if its colour does not change on more wetting.

Waterlogged: If water seeps or oozes out of the soil it is **Waterlogged**.

The soil water may be freely draining (or gravitational water), tenacious (or capillary water), or adsorbed (or hygroscopic, water).

Special formations: Special formations may be concretions, hardpans and the like. Iron pans are common in Ceylon soils. Lime concretions, iron stones, silica and clay hardpans, occur frequently.

Drainage: Soils show various degrees of drainage, from well-drained to impeded. Sandy soils are well-drained while clays are impeded.

The level of the permanently waterlogged soil is called the ground water table. The height of the water table would signify the type of drainage prevalent in the soil. Coarse textured soils are **excessively** drained. If the level of the water table is permanently below six feet the drainage is **good**. Higher levels of the water table would indicate whether the drainage is satisfactory, deficient, or impeded. For example a water table near the surface would signify **impeded** drainage. A water table between 1 and 3 feet during the dry season indicates **deficient** drainage; that between 3 to 6 feet shows it is **satisfactory**.

Water-holding capacity: Clays have a higher water holding capacity than sands. In fact water merely percolates through sands without being retained whereas clays absorb and conserve it.

Soil porosity: This is the space in the soil not occupied by solids. The pore space has air and water (in solution form).

The pore space in Simple soils rarely exceeds 50 percent but, it is over 70 percent in Aggregated crumb types.

Type	Pore space
Sands	32%
Loams	42%
Clays	48%
Aggregates	70%

The porosity generally indicates the aeration of a soil and its water-holding capacity.

The Soil Fauna and flora: The presence of particular types of fauna and flora can indicate various soil conditions. Earthworms for instance, signify that the soil is quite fertile and that it has a good structure. It is best to distinguish the microscopic forms from the macroscopic types because the effects of the former are more chemical and the latter physical.

Chemical properties: Soil reaction is expressed as acid, alkaline or neutral. Acidity and alkalinity can indicate many things in a soil.

The chemical activity is restricted to the smallest fractions in the soil such as the clays and humus. These are negatively charged particles which retain positive particles, as for example, calcium, potassium, sodium, ammonium and so on. A soil rich in these alkaline earths would give an alkaline reaction, as for example limestone soils. On the other hand organic humus is acidic in reaction; and soils that have an accumulation of it will give an acidic reaction. Plants tolerate acidity better than alkalinity. Limestone soils can be tested with any inorganic acid: the addition of acids to such soil causes effervescence.

Soil acidity or alkalinity is indicated by *ph* values. This is just a scale of values just as inches are a scale of distance. *Ph* values range from zero to fourteen. Those values between 0 and 7 are called acid, and those between 7 and 14 are alkaline. *Ph* 7 itself is neutral. For example pure water has a *ph* of 7 and so is neutral.

Plants thrive best between *ph* 6.6 and 7.3. *Ph* of over 8 are toxic for most plants; so are *ph* below 4. *Ph* near 4 and 5 are found only in very wet areas containing Peats or in bogs. *Ph* near 8 are found in certain limestone and saline soils. The *ph* changes with depth too.

The *ph* range for plants is listed.

<i>ph</i> 4.5 or less	...	very strongly acidic.
<i>ph</i> 4.5 to 5.2	...	strongly acidic.
<i>ph</i> 5.2 to 6.6	...	mildly acidic.
<i>ph</i> 6.6 to 7.3	...	ideal for plants (nearly neutral.)
<i>ph</i> 7.3 to 8.0	...	mildly basic.
<i>ph</i> 8.0 to 8.6	...	basic.
<i>ph</i> over 8.6	...	strongly basic.

Dry Zone soils are nearly neutral or mildly acidic or alkaline. Wet Zone soils are invariably acid. Acid soils can be made alkaline by the addition of lime, while alkaline soils can be made more acidic by adding peats.

The range of plant growth in Ceylon is from *ph* 4.5 to 10.

Dry zone soils (Red Earths) ...	<i>ph</i> range 6 to 8
Wet zone (includes montane) [lateritic] ...	5 to 6
Saline soils ...	8 to 10
Lime soils ...	7 to 8
Peats ...	4 to 5

A method of determining *ph* in the field: Place a sample of the soil in a test tube and to it add a little Barium sulphate and distilled water. Gently shake the mixture and then add 2 or 3 drops of Universal Indicator in the process. The soil sample will now take some colour. This colour is then compared with that on a graduated colour chart from which the *ph* is read off directly, (*i.e.*, by matching the colours). The name of the Universal Indicator is not known since it is a trade secret of Australia.

If no universal indicator is available add some dilute hydrochloric acid instead. If there is no reaction the *ph* of the soil sample must be less than seven; if there is a reaction the *ph* is 7 or more.

In the laboratory elaborate meters are used to determine the *ph* of soil samples. Sometimes, there are plant indicators that indicate the reaction of a soil. Some plants are able to live in very acid soils while others live in very alkaline types. In Ceylon, for example, there are the salt plants that live in very salty alkaline soils alone and they serve as indicators for this type of reaction. Very acid soils usually, (particularly in bogs), have cyperus grasses, juncus, and eriocaulon. Mangroves live in alkaline soils inundated by brackish water; examples of such plants are Rhizophora, Ceriops, and Avicennia. In describing soil any useful indicator plants growing on it must never be overlooked, because they will indicate the total reaction from the point of view of the plant itself, (which chemical methods cannot do.)

Other methods: Shake a sample of soil with dilute ammonia and if it turns a dark colour the reaction is acidic.

Another method is to shake a sample of soil with an alcoholic solution of Potassium thiocyanate and if it turns blood red then its reaction is acidic. This experiment must be carried out under very dry conditions.

Indicators or dyes that have various colours at different *ph* values are commonly used in the field; they are

Dye	<i>ph</i> range.
Bromcresol green ...	3.8 to 5.6
Chlorphenol red ...	5.2 to 6.8
Bromthymol blue ...	6.0 to 7.6
Phenol red ...	6.8 to 8.4
Cresol red ...	7.2 to 8.8
Thymol blue ...	8.0 to 9.6

FERTILISERS, AND THEIR USES

Source of plant nutrients: The total capital of plant nutrients is contained in the mineral constituents of the soil which is obtained by rock weathering, in the soil water and air, in the organic remains of plants and animals decaying in the soil, and in the body constituents of the plants and organisms living in the soil.

Plant nutrients: From this principal capital of nutrients plants obtain certain elements which are absolutely essential for their growth; the elements they need are Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S), Calcium (Ca), Magnesium (Mg), Iron (Fe), Manganese (Mn), Boron (B), Copper (Cu), Zinc (Zn), and Molybdenum (Mo)..... altogether fifteen elements.

Major and Minor elements: Of these elements the first nine elements C, H, O, N, P, K, S, Ca and Mg, are required in relatively larger amounts than the remaining six Fe, Mn, B, Cu, Zn, and Mo; these are required only in traces. The former group are called Major elements and the latter Minor elements.

Of the nine Major elements C, H, and O are present in profusion in all soils as water (H_2O) and air (CO_2 etc.), and are thus freely available to the plants provided there is no shortage of water as in a drought.

The balance six Major elements (N, P, K, S, Ca, and Mg) are obtained directly or indirectly solely from the soil itself: of these the last three S, Ca, and Mg are generally found in plenty in all soils, and their soil compounds are relatively insoluble too so that they are well fixed. Therefore, shortages of these three elements are rare indeed. Shortages of Minor elements too are rare for the same reasons.

Causes of nutrient deficiency: On the other hand N, P, and K salts occur only sparingly and these forms are readily soluble and lost in solution if they are not fixed. Normally, in mature undisturbed soils, as for example under high forest, the nutrients rotate between the trees and the soil in cycles in a state of dynamic equilibrium. For instance, the plants fix the nutrient salts of N, P, K, and others in their bodies by absorption, and they release these minerals back again to the soil by death and decay with the help of micro-organisms, to be reabsorbed by other plants in the vicinity; these are the familiar Nitrogen cycles, Phosphorus cycles, Sulphur cycles, Minor element cycles, etc., that occur in soils under plant cover.

These are the ways in which soluble and scarce N, P, and K (and other nutrients too) are fixed without loss by this interaction between plants and the soil. But if this delicate equilibrium existing between the plants and the soil in relation to nutrient elements, especially N, P, and K, is upset namely by clearing, grazing or burning, they are readily lost by leaching in the next rains as they are soluble, and as the plants are no longer there to fix and rotate these scarce elements: the result is that shortages of N, P and K occur in the soil. This, however, does not apply to the other Major elements (S, Ca, and Mg) and the Minor elements because their soil compounds are relatively insoluble and therefore stable and as they usually occur in abundance. Similar shortages are likely to occur by harvesting and removal of a crop, for part of the nutrient capital is actually physically removed in this way. Therefore, if soils are disturbed by man's activity or otherwise, the plants growing on them will show deficiency symptoms of N, P, and K after some time.

Deficiency symptoms: Nitrogen: N. A deficiency of nitrogen in plants is indicated by the stunting of the plants, by the uniform yellowing of the leaves which also drop early, and by the early death of lateral buds. Generally, nitrogen occurs in relatively smaller amounts in the Dry Zone soils than in the Wet Zone soils because the rate of decomposition is much faster in these moist dry climates. The N content of Ceylon soils is generally poor and averages around 0.2 percent.

Phosphorus. P: P deficiency in plants is shown by the characteristic bronzing of the leaves and the purpling of the veins. Further, the plants may develop coarse brown rootlets. Flowering and fruiting may also be retarded. Generally all Ceylon soils are deficient in P because phosphate bearing rocks are scarce, and the average is less than 0.1 percent.

Potassium. K: Shortages of K in plants is evident if the leaves turn yellow at the tips and the margins, and if this yellowing spreads inwards along the veins of the leaves. Dry Zone soils are well supplied with K while Wet Zone soils are relatively poor. In Ceylon as a whole the K content of soils is satisfactory and around 0.2 percent.

Lack of any nutrients in a plant can also be determined by chemical analysis of the leaves of suspected plants or of the soil itself.

USE OF FERTILISERS:

Deficiencies of any nutrient element such as N, P, or K can be easily rectified by the judicious application of fertilisers containing them to the affected soil. Fertilisers are of organic or inorganic origin. They are substances that contain one or more nutrient elements required by plants for their healthy growth, in certain desirable proportions.

Inorganic fertilisers are generally cheaper, less bulky and are usually required in much smaller dosages than organic fertilisers to give comparative results. Organic fertilisers have the added disadvantages that they can introduce certain parasitic organisms and weeds and toxic substances such as ammonia.

Grade of Fertiliser: The amount of N, P, and K (or other element) in fertilisers is indicated by the percentage numbers of each in a substance present in a certain manner. Nitrogen is shown by the percentage of available Nitrogen in the compound: P and K are indicated by the amount of water soluble oxides P_2O_5 and K_2O respectively in it. For example, the fertiliser Ammonium Phosphate has 16 percent of available Nitrogen and 20 percent of water soluble P_2O_5 (i. e. Amm: Phosph: = 16 N & 20 P).

The following are the commercially available fertilisers.

INORGANIC FERTILISERS.

Nitrogen fertilisers: (N). The most common N fertilisers are Chile Saltpetre (sodium nitr.) 16. N, Ammonium sulphate (21 N), Ammonium nitrate (35 N), Calcium cyanamide (20 N), and Calcium nitrate (16 N). Of these, never use Ammonium sulphate on very acid soils, such as peats, bogs, wet grasslands, and soils of extremely wet areas, because it decomposes in solution to an acid which will only increase the already harmful acidity, existing: in such soils use Sodium nitrate or Urea, or Calcium nitrate. On the contrary use Ammonium sulphate on very alkaline soils (limestone soils) to reduce their alkalinity. Some slow release Nitrogen fertilisers are Urea-formaldehydes and Mag; Ammon; Phosphate..

Phosphorus fertilisers: (P) The phosphorus fertilisers usually sold are Saphos (Rock) phosphate (30 P), Super phosphate (18 P) and double Super phosphate (42 P). The super phosphates are obtained by the action of acids (e.g., phosphoric acid) on Rock phosphate. Rock phosphate is the most insoluble form of the three types mentioned. It is therefore used in all places with an excess of water (bogs, fields) for this form is retained longer without early solution and consequent loss. The more soluble super phosphates could be used in drier locations. Basic Slag (8 to 18 P) from steel works-waste is another good Phosphorus fertiliser.

Potassium fertilisers: (K) The K fertilisers normally available are sulphate of Potash (48 K) and Mureates of Potash (50 to 60 K). The muriates have the chloride ion (cl.) which may be toxic to certain plants: in such situations use Potassium sulphate instead.

Combined fertilisers: If one of the elements required for plant growth is scarce in a soil then the use of an appropriate fertiliser containing the deficient element could rectify this fault. More often two or more elements are deficient in infertile soils. In this case a single chemical compound containing two or more of the appropriate missing elements could be simply applied, as for

example Potassium nitrate (16 N & 45 K) or Ammonium phosphate (16 N & 20 P). Here the ratio of one deficient element to the other is constant, unlike in the case of Complex fertilisers.

Complex fertilisers: It is known that if one or more of the nutrient elements are absent or are not in the correct proportions, then the others are rendered inactive or are not absorbed at optimum values. All nutrient elements must be present in the correct proportions for all of them to give maximum results.

To get N, P, and K fertilisers all together, and in the right proportions two or three simple fertiliser compounds are mixed in the desired ratios; they are called Complex fertilisers. One such popular mixture is Ammonium phosphate, Potassium nitrate, and Ammonium sulphate, in various N, P, K combinations such as 8: 4: 8. Generally, these Complex inorganic fertilisers will rectify all nutritional deficiencies at one and the same time. It is always safer to apply a Complex fertiliser than a simple one because it is usually found that if one element is lacking the others are missing too. In Complex fertilisers the ratio of one missing element to the other can be regulated as desired by mixing appropriate quantities of simple fertilisers.

ORGANIC FERTILISERS:

Organic fertilisers are of animal or vegetable origin. They may have one or more nutrient elements.

Organic fertilisers of vegetable origin are composts (N: P: K: = 0.5; 0.2; 0.5), wood ash (5 K), litter, and others. Litter is easily collected from the topsoil of any forest. Composts are fertilisers solely of vegetable origin such as peat, litter or humus, which are stratified with little inorganic commercial fertilisers and allowed to ferment and decompose in pits. Peats (1N), Tea foliage (2.5N), Erythrina leaves (4N), Poonac (3N), Ground nuts (8N), Gliricidia (3N), are good green manure mulches. Inorganic fertilisers of animal origin are slaughter-house refuse, sewage sludge, bone meal, meat meal, bird droppings, fish flour, wool, hair, and farm yard manure. The last named, farm yard manure is mainly animal urine absorbed in decomposing litter or peat or dung. It is always advisable to compost dung before use or else it can introduce weeds and other pests.

Name of fertiliser:

Name of fertiliser	%N	%P	%K
Animal Or:
Sewage sludge	6	—	—
Urea	46	—	—
Blood meal	11	—	—
Meat meal	7	10	5
Bone meal (boiled)	3	22	—
Fish flour	4-7	4-8	6
Hoof and horn	8 to 13	—	—
Farm yard manure	0.6	0.35	0.5

In general inorganic fertilisers are the richest in nutrients, while those of animal origin come next, and last come those of vegetable origin.

Dosages of fertilisers: There are no fixed rules regarding the amount of fertiliser to be used on any particular plant since so many factors have to be taken into account such as the type of species, soil, climatic regime, topography, size of plant, etc. The dosages to be applied to a particular plant to obtain maximum results in the environment it grows, are usually found out by experimenting. Generally, the agency that markets any particular type of fertiliser will give the dosages to be applied to named plants.

In the absence of such information inorganic fertilisers (Complex) can be applied thus; use 5 to 10 pounds on a huge tree (e.g. coconut) per year, 2 to 5 pounds per year for a small tree (e.g. Rubber), 1 to 2 pounds per year for pole-sized plants (e.g. Papaw, Citrus) and below one pound for shrubs (e.g. Tobacco, Cinnamon, Tea). On the other hand organic fertilisers have to be used in much larger dosages to produce the same results as those from inorganic sources. Ten tons of compost fertiliser is the equivalent of 550 pounds of Ammonium sulphate, 250 pounds of Super phosphate, and 300 pounds of Potassium chloride (Muriates).

Toxicity: The correct dosages of fertilisers must never be exceeded because they tend to be toxic in excess, and they may have the opposite effect intended, especially in the case of inorganic fertilisers. Further, above an optimum value, fertilisers have no effect on yields or plant.

Application of fertilisers: Fertilisers are either broadcast sown, dibbled in, or sprayed in solution, to the affected soil. Never put fertilisers directly on to the vegetative parts of plants (e.g. leaves) because they may cause burns. It is better to apply fertilisers regularly in small dosages over the year than to give large irregular dosages. In the absence of any other criteria apply the fertiliser in small dosages every four months to make up the total to be used for the year. The first dose may be given after the plants have just sprouted from the ground and put on two leaves; generally a handful of fertiliser suffices at this stage. In the case of annuals similar doses may be given just before flowering and fruiting. In the case of all other plants apply the fertiliser in small doses every 4 months.

Method of application: If the plants are small the fertiliser can be given as a top dressing into the soil near the roots. But if the plants are trees dibble the fertiliser into the soil in a wide circle marked by the outer circumference of the crown.

The success or failure of the application can only be judged by looking at the plant itself. If the plants are green and robust with large leaves and internodes then the operation has been a success. High yields can then be anticipated.

SOIL EROSION

The erosion of the soil has been going on from time immemorial. This is called natural erosion and usually this process is very slow and insidious, except when cataclysms (earthquakes, cyclones, etc.), accelerate it. This type of natural erosion can hardly be prevented.

However, when man interferes in the natural order of things in the soil, erosion is artificially accelerated. This erosion can be prevented or minimised. Man interferes in the soil by cultivating, mining, burning and grazing. By these processes man lays bare the land to the agents of erosion, as for example by removing a protective forest cover.

In Ceylon, soil erosion is caused by water and wind.

Water erosion: Soils liable to erosion have poor infiltrating capacity and have no power to drain the water away. This water that is unable to seep or percolate into the soil merely runs off the surface carrying earth in suspension or solution, causing erosion.

Besides, large drops of water mechanically beat the soil and break up any good structures in the soil (example, crumb formations) and thereby they cause compaction. The larger the drops the greater the power of compaction. Thus in the low country, where rain drops are generally of large sizes, this danger is greater, than in the upcountry, where they are smaller; in fact rain falls in a fine spray for most of the time at the highest elevations. The final result of compaction is that the percolating capacity of the ground is extremely reduced and water tends to run-off the surface, carrying soil with it.

The duration of the rainfall is another important consideration to be taken into account in erosion. In a dry soil any rain falling for a short time will be absorbed by seepage. But, if the rains

continue for long periods over the same soil it gets soaked and saturated, and it is unable to absorb any more water. The unabsorbed water will then run off the surface causing erosion.

The amount of rain also has a direct bearing on erosion. A heavy shower over a short period can cause more damage than a light shower over a long period.

The more intense the rains the greater the run-off and consequent erosion.

The lay of the land or topography affects the rate of erosion profoundly. On perfectly level land and plains erosion is slight or non-existent, but, on sloping ground erosion is rampant, because run-off is facilitated. The rate of run-off, and incidentally erosion, will vary directly with the degree of slope. This is the reason erosion is so prevalent in the hill slopes of Ceylon. Further, the greater the gradient of the slope the greater the velocity of run-off. Coupled to this, the carrying power of the water will vary with its velocity too, which will be greatest on the steepest slopes. It is for this reason that the upcountry soils must be managed with the greatest of care and respect.

Types: For practical purposes two types of erosion can be recognised; they are **sheet** and **gully** erosion.

Sheet erosion is very unnoticeable. Here the topsoil is quietly eaten away in a uniform surface layer. This type of erosion takes place with the less intense rains. When the rains become more intense channels are cut on the soil surface, which get deeper with time. These channels all lead to permanent drainage channels, streams and rivers. These channels or gullies can be anything over two feet in depth. This type is called **gully** erosion.

Protection measures: All soil protection measures are designed to minimise or eliminate run-off and compaction. The addition of organic matter and lime prevents compaction. Ground cover too breaks the fall of raindrops and by doing so prevents

compaction. Organic matter is spongy and absorbs and retains large amounts of water which would otherwise run-off; thus, by increasing the percolating power of water, erosion is checked.

Run-off, which is most prevalent on hills, can be prevented or reduced by terracing the land. Terracing is the creation of horizontal steps on hill slopes, on which cultivations or other operations can be carried out. Similar effects to terracing can be obtained by contour ploughing, planting and draining. In contour ploughing the plough lines go along the contours. In contour - planting the plants must be established as close to each other as possible along the contour lines.

Similarly, contour-drains are made alongside contour lines with slight gradients near 1 in 100. These drains have silt pits along their length to collect eroded materials. The drains ultimately lead to permanent drainage channels. In Ceylon closed drains or pipe drains cannot be used in erosion work for they get clogged quickly; open drains are the rule here.

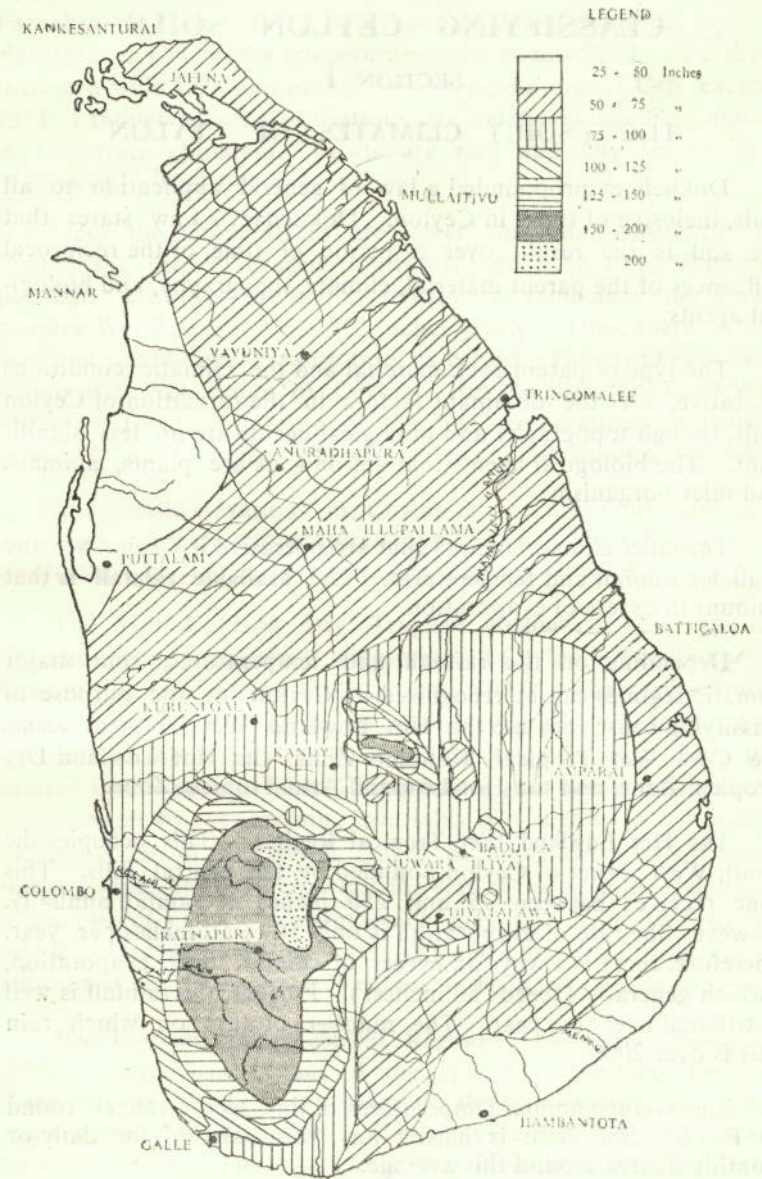
In all lands subject to erosion, burning and grazing must be discouraged. Cultivations, if avoidable, must never be done on such land for it may result in the ultimate degradation of these lands. In fact it is best to keep these unstable lands under natural vegetation of forests and grasslands. Forests are more effective in checking erosion than grasslands, because they have deep penetrating root systems which fix the soil better; and they also make the soil crumbly aiding seepage and reducing run-off. Other soil conserving methods are more elaborate and akin to engineering works, such as the building of masonry retaining walls, check dams, and anicuts.

Another source of soil erosion in Ceylon is wave action on the beaches. In such soils all types of interference likely to increase erosion should be stopped. All natural plant cover must be retained. All mining by the coast must be halted. Engineering works of rock walls, concrete beach-heads and other structures, are effective in checking erosion.

Wind erosion: This is most prevalent in the coastal belt of Ceylon and in the Upcountry where average wind velocities are high. Wind erosion is most rampant in open bare land rather than on land that has some form of cover. Wind erosion can be checked locally by planting windbelts in erodible areas. The windbelts must be established at right angles to the prevailing wind direction for them to be effective. Any sort of ground cover will also minimise this type of erosion. In areas subject to severe wind erosion the land must be managed carefully preventing any activity that may enhance the damage; thus, as in the case of water erosion, cultivations, grazing, burning, and mining, must be frowned on. Natural forests should never be cleared from the high ridges and mountain peaks for they act as windbreaks.

The prevention of soil erosion should be a primary object in Ceylon, for the topsoil consists of one of our chief natural resources on which grow our chief agricultural products, Tea, Rubber, Coconut, and Paddy. In fact, the soil itself is our lifeblood.

ANNUAL AVERAGE RAINFALL MAP
OF CEYLON



CLASSIFYING CEYLON SOILS

SECTION I

THE (SOIL) CLIMATES OF CEYLON

Dokuchaev propounded a law of general application to all soils, inclusive of those in Ceylon. Dokuchaev's Law states that the soil is the result, over a period of time, of the reciprocal influences of the parent material, climate, topography, and biological agents.

The type of parent rock material and the climatic conditions operative, are the dominant factors in the formation of Ceylon soils, though topography and biological agents are no less significant. The biological agents that act on soils are plants, animals, and micro-organisms.

The chief climatic factors that are operative in Ceylon are the **available rainfall** and **temperatures**. The **available rainfall** is that amount in excess of evaporation.

Depending on the rainfall and temperatures, four major climatic regimes can be recognised in Ceylon for the purpose of classifying soils; they are the Hot Lowland Wet Tropical Zone, the Cool Wet Tropical Montane Zone, the Hot Lowland Dry Tropical Zone, and the Hot Lowland Arid Tropical Zone.

The Hot Lowland Wet Tropical Regime: This occupies the South West corner of Ceylon bounded by the central hills. This zone receives between 75 and 250 inches of rainfall annually. However, the rate of evaporation is only 50 to 60 inches per year. Therefore, there is always an excess of rainfall over evaporation, (which generally exceeds 50 inches.) Further, the rainfall is well distributed over the year. The number of days on which rain falls is over 200.

The average annual temperatures in this sector ranges round 80° F. Besides, there is hardly any variations of the daily or monthly figures around this average.

The climate is hence very hot and wet, without droughts.

The Cool Wet Montane Tropical Regime: On the other hand, in the hill country the temperature drops one degree Fahrenheit for every 300 feet of elevation. Therefore, in the highest elevations in Ceylon the temperatures vary round 57° F. Further, there is a wide variation in the daily temperatures (Can exceed 15° F.) though seasonal variations are relatively small (unlike in temperate climates). Frosts are rare and day lengths are constant (12 hrs.) too.

Since the temperatures are lower here than elsewhere in Ceylon the rate of evaporation too is reduced to 40 to 50 inches per year. However, the rainfall remains the same as in the Low-country Wet Zone, of 75 to 250 inches yearly. Thus, there is an excess of rainfall over evaporation, as before. The area hence falls within the Wet Zones of Ceylon: But the climate is Cool Wet Montane Tropical because of the low temperatures prevalent. Here too there are no drought periods. (Rain falls for over 200 days)

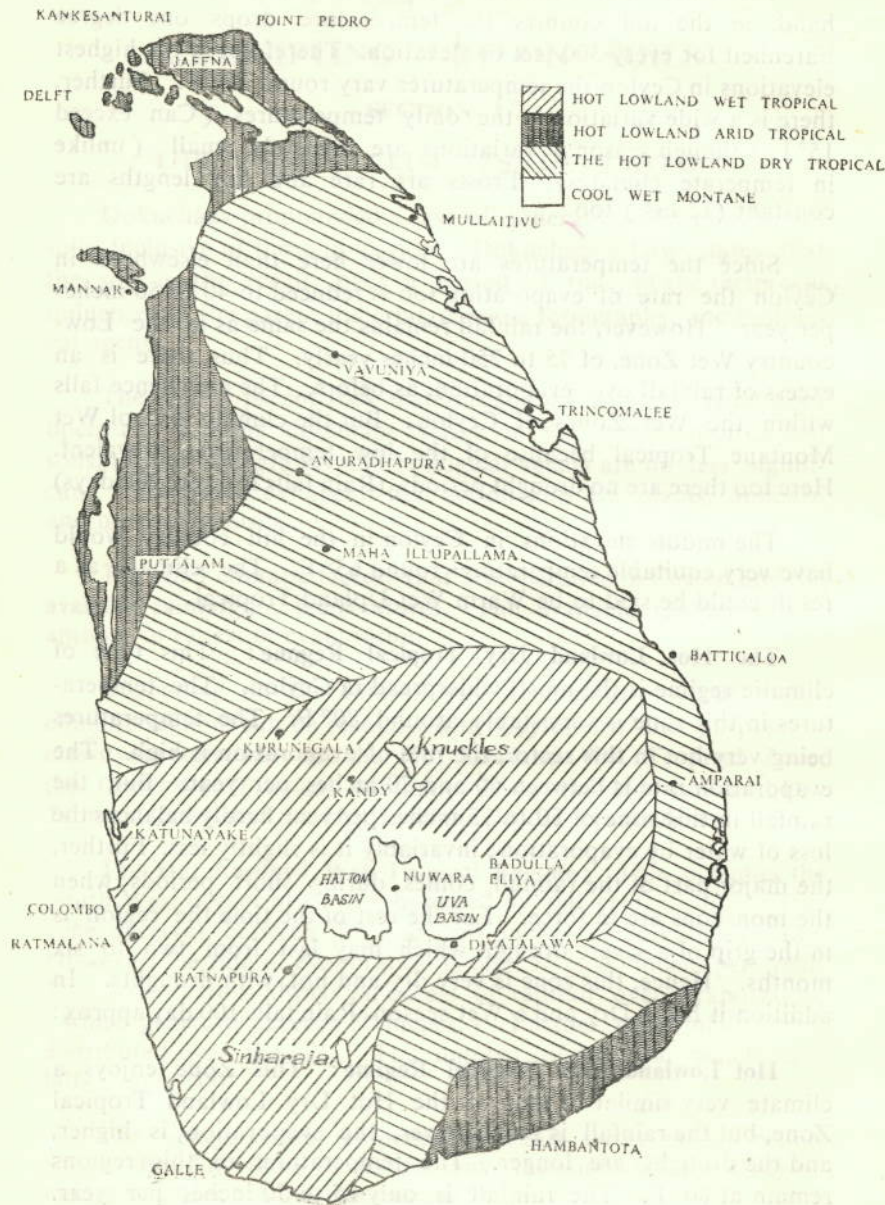
The middle elevations in Ceylon in the hill country would have very equitable temperatures round 65° F. The climate as a result could be said to be Warm Wet Upland Tropical.

The Hot Lowland Dry Tropical Regime: This type of climatic regime is the most widespread in Ceylon. The temperatures in this zone is very stable around 80° F. The temperatures being very hot in this sector, the rate of evaporation is high. The evaporation rate is between 60 and 70 inches per year. But, the rainfall in this zone of 50 to 75 inches per year hardly balances the loss of water by evaporation; invariably it is slightly less. Further, the major part of the rainfall comes during short periods when the monsoons are in force. For the rest of the time the region is in the grip of a severe drought which may last from two to six months. Hence, this zone is very dry and hot, with droughts. In addition it has a Dry and a Wet season. Rain falls 100 day approx:

Hot Lowland Arid Tropical Regime: This Zone enjoys a climate very similar to that of the Hot Dry Lowland Tropical Zone, but the rainfall is much lower, the evaporation is higher, and the droughts are longer. The temperatures in this regions remain at 80° F. The rainfall is only 25 to 50 inches per year.

THE SOIL CLIMATES OF CEYLON

Map compiled by S. N. U. Fernando



Thus, there is a deficit of rainfall, for the rate of evaporation is 70 to 80 inches yearly. The droughts too extend for over 6 months of the year. The climate in these regions is very rigorous and harsh, when compared to that of the rest of Ceylon. Hot temperatures, deficit rainfall, and severe droughts, are characteristic of this zone. This arid zone is in two parts, one occupying the North-West of Ceylon and the other the South East. The South-Eastern part of the Arid Zone is underlain by gneisses, while the North-Western sector is underlain mostly by Miocene Limestones.

Seasons are most marked in this zone in Ceylon; there is a long Dry drought period alternating with a short (3 months, Dec. — Feb.) rainy season every year.

SECTION II

THE SOILS OF CEYLON

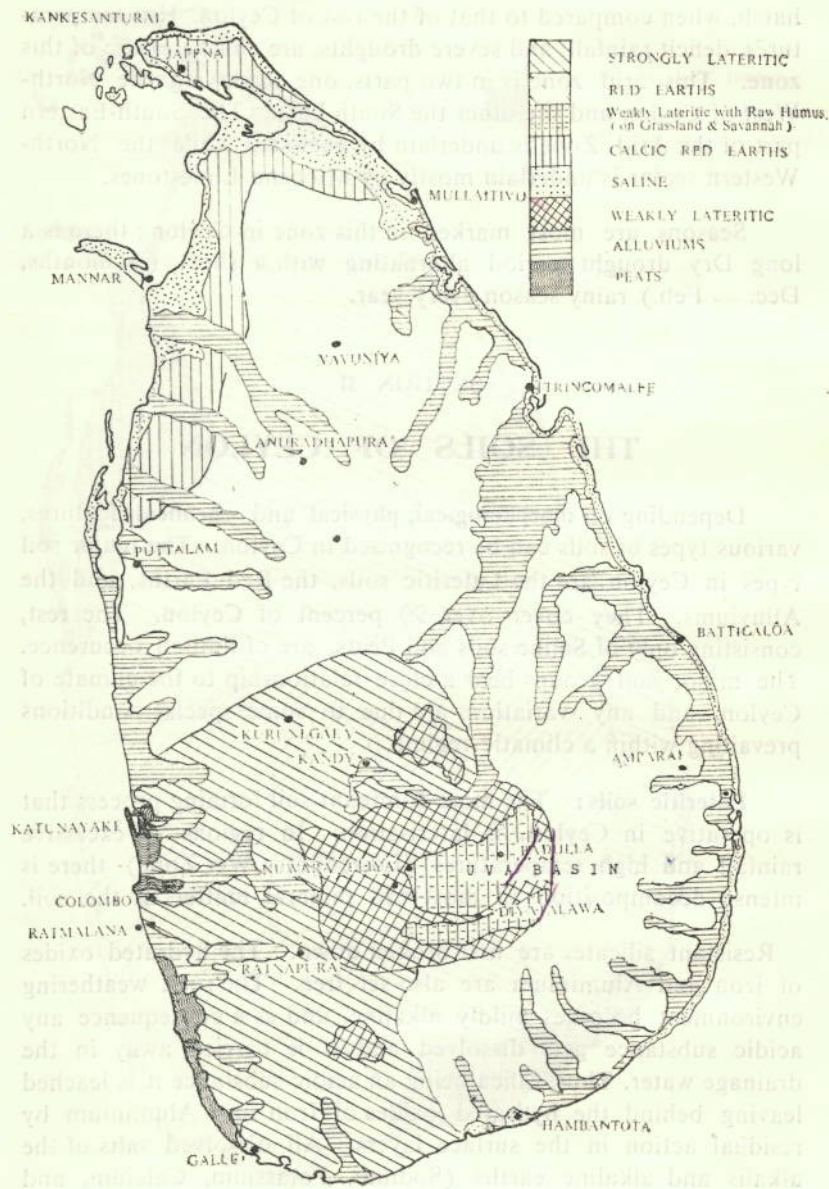
Depending on **morphological, physical and chemical** features, various types of soils can be recognised in Ceylon. The major soil types in Ceylon are the Lateritic soils, the Red Earths, and the Alluviums. They cover over 90 percent of Ceylon. The rest, consisting only of Saline soils and Peats, are of limited occurrence. The major soil groups bear a close relationship to the climate of Ceylon, and any variations are due to some special conditions prevailing within a climatic regime.

Lateritic soils: The most dominant soil forming process that is operative in Ceylon, is laterisation. In regions of excessive rainfall and high temperatures (Lowcountry Wet Zone) there is intense decomposition of most raw mineral matter in the soil.

Resistant silicates are first broken down. The hydrated oxides of Iron and Aluminium are also set free. The rock weathering environment becomes mildly alkaline, and as a consequence any acidic substance gets dissolved and it is carried away in the drainage water. Thus, Silica being an acidic substance it is leached leaving behind the hydrated oxides of Iron and Aluminium by residual action in the surface layers. All dissolved salts of the alkalis and alkaline earths (Sodium, Potassium, Calcium, and

THE SOILS OF CEYLON

Map compiled by S. N. U. Fernando



Magnesium) are also lost in the leaching water (as they are very soluble.) The net result of leaching then is that the surface layers of the soil gets desilified and in the process they get enriched mainly with Iron oxide (hydrated.) The Iron oxide being hydrated, it gives a mottled reddish-yellow colour to the soil, Other colour variations such as reds, pinks, and yellows, are also possible

If this process of desilication goes on to its logical end a final product consisting entirely of the hydrated oxides of ferric iron with little Alumina, and sand will be formed. Sometimes this end product is very indurated or hard, and is known locally as Cabook, a building stone. The oxide content of iron in Cabook may be over ninety percent while the silica content may be lower than two percent; such soils are called Laterites. They are the only true Laterites in Ceylon, The principal clay in Laterites is kaolin (not Temperate montmorillonite). Ceylon Laterites have little alumina (1 to 2%).

Thus, a typical lateritic profile will show the following features. The surface horizon, A that is enriched with iron, will display a bright reddish - yellow colour which may show signs of mottling. Often organic matter is incorporated into this horizon separating a surface humus layer (A_0) from a Silica leached substrate (A_1). Below this is a horizon which will be pale in colour for it is enriched in Silica brought down from the higher layers; this pale zone is called a pallid horizon (B). Below the pallid zone will be the usual C horizon of parent material; which usually has rounded boulders embedded in it. These boulders peel in characteristic onion skin fashion when they weather. The bedrock below the parent material is the D horizon, and it is usually a well weathered rock of charnockite.

Laterisation, hence, consists essentially of the removal of silica, lime, magnesia and alkalis leaving residual iron oxide behind. Ceylon laterites are thus ferruginous laterites, and not very bauxitic (little alumina). The chief clay mineral in them is kaolin.

Relict laterites, formed on peneplains, which were subsequently uplifted, are absent in Ceylon mountains; that is, no cabook is found capping Ceylon hills (unlike in Australia and Africa,) because of tectonic activity. All laterites in Ceylon are formed in situ.

such as Eucalypts, grow to enormous heights when grown on these weakly lateritic soils (some Eucalypts grow on laterites in Australia).

Thus, the effect of altitude in Ceylon is to retard laterisation. In general, strong laterites can be met with in the lowest elevations while weaker and weaker types will be met as higher and higher altitudes are reached. These weakly lateritic soils have a silica to alumina ratio around 1.7. Humus, though not so completely decomposed as in the lower elevations, is generally well incorporated into these weakly lateritic soils at these higher altitudes. These types could be strictly defined as **Humus Incorporated Weakly Lateritic Soils**. They are common under all forests and tree cover of these higher zones.

- (b) But under grasslands, for a variety of factors, chiefly, **continual burning**, organic matter tends to accumulate, without decomposing and incorporating into the soil. Sometimes the humus layer can be over two feet in thickness, as on the Wet (Patana) Grasslands. More often it is a few inches thick as on the Dry (Patana) Grasslands and Savannahs of the upcountry. The Wet Patana Grasslands occur in the highest elevations of Ceylon over 6000 feet; the Dry (Patana) Grasslands occur between 3000 and 6000 feet, and the Savannahs around 2000 feet. Here, the biological factor (burning of grasses) has a definite effect on the formation of this type of soil. These soils could be said to be **Humus Unincorporated Weakly Lateritic Soils**. If the grasses are eliminated, for example by stopping all burning operations in them and by replanting with trees, these soils would probably turn into Humus Incorporated Weakly Lateritic Soils. These raw humus soils are very common in the Uva Basin, Hatton Basin, Horton Plains, N'Elia, Ohiya Plateau, and in all places over 2000 feet in elevation. The Wet Grassland soils occur in high rainfall (over 90 inches) and low temperature zones over 6000 feet, while

the Dry Grassland soils cover the drier (rainfall usually 80 inches) and warmer regions (3000 to 6000 feet). The Savannahs also occupy the lowest regions where these Dry Grasslands occur (2000 feet commonly).

The Red Earths: These are another group of soils where the climate plays a dominant role in their formation. They are found all over the Dry Zone of Ceylon, where the climate is Hot Dry Tropical with a pronounced period of drought. They are also found in the non-limestone areas of the Arid Zone. The droughts in both these zones may extend from 2 to 8 months, in a year. The annual rainfall is hardly sufficient to balance the evaporation in these regions. Besides, the rain falls only for short periods, invariably during the N. E. Monsoon. The Red Earths have a Silica to Alumina ratio of over 2 generally. The high temperature conditions, coupled with periodic droughts and low rainfall, are responsible for the rapid decomposition of minerals (and humus) which give a mild acidity, generally around *ph* 6 and 7. The mild acidity is insufficient to dissolve and leach the fairly insoluble compounds of iron and aluminium. However, the soluble alkali and alkaline salts are brought into solution and translocated to lower horizons of the soil. A certain amount of desilication also goes on. However, during the severe droughts some of these materials that are translocated during the rainy season, are brought to the surface layers by upward leaching. Any of these materials that may be permanently lost by downward leaching during the rains are replenished by rock weathering. Therefore, there is always a sufficient amount of bases to balance that which is lost by leaching. The net result of all these processes is that desilication is partial though the content of iron oxide (ferric) and aluminium oxide increases by residual action just as in the case of laterites. But in these dry climates the iron oxide is non-hydrated. This non-hydrated oxide of ferric iron gives a uniform red colour to these soils; hence the name Red Earths. (The oxides in laterites are always hydrated for the soils are permanently moist and never dry since they occur in very Wet areas.) Soil horizons are difficult to distinguish.

The humus in these soils has only a transient or momentary existence since it is rapidly decomposed and utilised by plants, or is lost by leaching just as in the case of laterites. Whatever humus

that is present gives a brown colour to the surface layers. Thus, the overall colour of the surface horizon of these soils maybe reddish - brown. But, below this the soil will be unmottled and uniformly red till the parent material is reached; (hence, the name of these soils.)

In texture these soils range from light to heavy loams. A gravelly subsurface horizon is often met with in these soils. These soils are non - lateritic, as the ratio of Silica to Alumina is over 2.

Here too, as in the case of lateritic soils, various grades of Red Earths are recognisable. Most types are typical Red Earths, while others are close to the lateritic boundary particularly those found in higher rainfall areas of the Dry Zone, with very short periods of drought. (Long droughts inhibit laterisation).

The Red Earths are found all over the North Central, Eastern, and Southern parts of Ceylon. They are the most extensive soil types found in Ceylon.

These soils are underlain by rocks such as gneisses, quartzites, granites and charnockites. The northern and southern sections of the Red Earths are underlain by gneisses and the centre by Khondalites.

Calcic Red Earths: The typical Red Earths are found outside the limestone areas of Ceylon as said before. The Calcic Red Earths are merely Red Earths over limestone. They occur chiefly in the Arid Zones of Ceylon, where the climate is Hot Arid Lowland Tropical, with pronounced periods of drought. All the processes that go on in typical Red Earths go on in these soils too. But, owing to the limestone bedrock an additional process also goes on. Water percolating through these soils has Carbon Dioxide gas from the air dissolved in it as carbonic acid, just as in the case of all leaching water in the other types. But this carbonic acid solution has the power of dissolving the relatively insoluble Calcium carbonate in the limestone, to the more soluble Calcium bicarbonate which gets leached down as usual with the other alkaline and alkali salts. During the drought this bicarbonate is brought back to the surface along with the other salts. On reaching the surface the Calcium bicarbonate is decomposed back

again to the original Calcium carbonate with the release of Carbon dioxide gas. Thus, it is usual to find free lime in these soils. As a result the soils are alkaline unlike in the case of the typical Red Earths with *ph* around 7 and 8; that is, these soils are mildly basic in reaction. In every other respect these soils resemble the Red Earths, as they are formed under similar climatic conditions. These soils illustrate the dominant role that can be played by geology in soil formation. The Calcic Red Earths have a silica to alumina ratio of over 2.5 generally, as in the case of typical Red Earths (non - lateritic)↓

(All soils in which the silica to alumina ratio is over 2 are non - lateritic.) These soils are non lateritic in nature, for there is insufficient rainfall, to cause total downward leaching unlike in laterites. The importance of the drought, in the formation of all Red Earths and in retarding laterisation, must be emphasised.

These soils too are deep, porous, and freely draining as in the case of typical Red Earths. The free lime does not mask the colour of the non - hydrated oxide of ferric iron which is present, so that these soils too are uniformly red just like typical Red Earths.

The limestone bedrock in these soils may be at the surface or it maybe below at varying depths, generally around six feet.

In texture the soils range from light to heavy loams. Frequently the surface layers may be sandy but lower down it is usually clayey.

The largest extent of Calcic Red Earths occur in the limestone districts of Jaffna and North East Ceylon. These limestones are of sedimentary origin of the Miocene Era when the whole of this area was under the sea. Small extents of these Calcic Red Earths are also found in the coastal coral limestone areas of the Hambantota District, in the Arid Zone. They may be found in the limestone (crystalline) districts of Polonnaruwa and similar localities, in the Dry Zone.

Alluvial Soils: These are more geological formations than soils. They are found in all the geological recent alluviums of Ceylon that occur all over the flood plains, terraces, and deltas, of

all the rivers in the island. The formation of alluvial soils is independent of climate. Therefore, it is usual to find them in all climatic regimes of Ceylon wherever rivers are eroding the land away.

The main soil forming process that occurs in these soils is merely the incorporation of humus from any vegetation that may be thriving on them. There is little or no leaching in these soils. These soils are very fertile as they consist mostly of the eroded topsoil of regions in the hillcountry. These transported soils have textures ranging from sandy to clayey loams. These soils are brownish in colour.

These alluvial soils are frequently waterlogged to varying depths. The waterlogged zone may be just below the surface or it may be lower down. The waterlogged zone can be recognised by the bluish-grey colour it possesses. As the soil is waterlogged all air is excluded from them so that reducing conditions prevail. Under these anaerobic conditions ferrous iron is formed instead of ferric. This ferrous iron gives a bluish-grey colour to the inundated zone. This is an example of gleyzation, (or water-logging).

Alluviums are examples of soils formed on transported materials. (Most Ceylon soils are formed in situ.)

Saline Soils: The characteristic of all Saline soils is that they display high *ph* values (8 to 10) owing to sodium salts; that is, they are strongly basic.

Typical Saline soils are formed under arid conditions with seasonal or temporary waterlogging. But, they could be formed as wave deposits too. Saline swamps, inundated by tides too have this type of soils.

1. **Typical Saline soils** are formed as a result of climatic conditions. They are usually evident under conditions of aridity and drought. Therefore, typical Saline soils are most common in the Arid Zones of Ceylon where the climate is Hot Arid Lowland Tropical with pronounced periods of droughts lasting over six months. In such extreme climatic regimes the net leaching is

upwards instead of downwards. Any leaching downwards during the rainy season of four months is counterbalanced by upward translocation during the remaining eight months. In these hot areas evaporation exceed rainfall by over thirty inches in general.

In such situations all salts that are leached downwards are not lost as these areas are usually impermeable and waterlogged, and during the drought the salts solutions are brought to the surface of the soil and deposited by recrystallisation, when the soil dries out. Hence, Sodium, Potassium, Calcium and Magnesium, which are the first to be leached in most soil forming processes, are present in the form of salts in the surface layers of this type. The most common salts that abound in these soils are Sodium chloride and Sodium sulphate, which give extremely high *ph* values between 8.5 and 10. Thus high *ph* values in these soils are the result of Sodium salts. (Calcium salts give lower *ph*..... see Calcic Red Earths.) These soils have Salt-Loving plants living on them (Halomorphs).

Wave deposits are Saline soils too for the same reasons but they are not, as is evident, formed owing to climatic conditions. They are merely deposits by the sea.

All Saline soils have very little humus for decomposition is rapid in these Arid climates.

2. Places permanently waterlogged by brackish water brought in by tides, in river mouths, tidal flats or basins, also have **Saline Swamp soils**; these are waterlogged Saline soils. These have mangrove vegetation on them. These Saline swamp soils are inundated at high tide; they dry out during the low tide. These soils are alkaline because of the inundation by salt water from the sea, which has an abundance of Sodium salts; they are not basic for climatic reasons. Peats, on the other hand, are permanently, waterlogged by fresh water, and are found in regions not subject to droughts (besides they are very acidic with low *ph*)

All Saline soils display a high conductivity (owing to Sodium). These soils can be improved by addition of Gypsum (Calcium Sulphate), Calcium chloride or Sulphur. The Calcium or

Sulphur replace the Sodium making the soil less alkaline (by reducing the *ph.*) Other methods of improving these soils are to add humus and to scrape off any superficial salt incrustation.

The largest extents of Saline soils, formed as a result of climatic conditions, are found in Jaffna, Paranthan, Mannar, Puttalam, Elephant pass, Hambantota, Nilaveli, and the South East coastal districts of Ceylon. Saline wave deposits are evident all along the dry zone coastline. Mangrove swamps are commonest on river mouths, or lagoons; examples are Negombo, Moratuwa, Bentara, Batticaloa, Mutur, and Galle.

PEATS: They, unlike saline soils, occur under conditions of permanently impeded drainage, or water-logging, in the very wet areas of Ceylon. They are formed under conditions of total waterlogging. The area where a peat is formed may be waterlogged because it is topographically lowlying, or it is in a hollow bounded by impervious rock, or it is underlain by clays. Besides, these areas are waterlogged throughout the year and not for a season.

Thus, peats are uncommon in the Dry and Arid Zone of Ceylon. Peats are examples of soils that could be formed because of some features in the topography, like a hollow.

As a result of the waterlogging all air is excluded from these soils and unaerobic conditions prevail in them. Therefore, the dominant form of decomposition is unaerobic too: this is a very slow process when compared with aerobic decomposition. The net result is that humus remains unincorporated and it collects as a thick mat over the soil. When this unincorporated humus layer is over one foot thick it is called a Peat. Peats can occur in hot or cool climates provided there is an excess of rainfall over evaporation. Further, the rainfall must be evenly distributed so that a Peat should never dry out. If it dries out, as for example during a drought, the humus will tend to decompose and get incorporated, so that the Peat will also automatically disappear. That is the reason why Peats become good soils once they are drained out. Because of the very acidic humus fraction in Peat they display a

low *ph* values around 4.5 to 5.5. Peats can have 15 to 60% of humus. Peats usually have a characteristic vegetation on them of *Cyperus*, *Juncus*, and *Eriocaulon* (Reed swamps).

Peats are more common in the Lowcountry (of the Wet Zone) than in the Upcountry. In the Upcountry, Peats are common only in the bogs in the Wet (Patana) and Dry (Patana) grasslands. Further, these Peats are not so deep as the ones found in the Lowcountry. The largest extent of Peats occur in the lowlying areas bordering the South West Coast. Examples of Peats are found in Muturajawela (Ja-ela), Moratuwa, Colombo, Bentara, Galle and Matara. It must be remembered that Peats are of very limited occurrence in Ceylon. They occur for some special reason that may be prevalent in an area. Peats can be easily identified by the black colour they possess owing to the humus.

Resume: Climatic factors acting on certain geologically weathered materials, are the main agents responsible for the formation of our major soil types in Ceylon, namely laterites, lateritic types, and Red Earths. Geology is the dominant force in the formation of Alluviums and Calcic Red Earths. Topographic features are the usual cause that gives rise to waterlogged Peats, and even Saline soils, with impeded drainage. Biological factors, such as the burning of grasslands, maybe the cause for the formation of Weakly Lateritic Soils with Unincorporated Organic Matter.

Therefore, it is seen that Dukuchaev's Law is well illustrated by Ceylon soils.

The formation of Ceylon soils is in the main controlled by climate, but, owing to some special reason within a climatic regime, pockets of specialised soil types may be found, namely, Peats, Saline Soils and Calcic Red Earths; in these cases other factors override climatic ones. Ceylon Soils are therefore best classified on the basis of the degree of leaching for this property is intimately connected to the climate.

The reduction of laterisation with altitude and droughts is noteworthy. This is indicated even by the ratio of Silica to Alumina, which is low in Wet Lowcountry soils (around 1.33),

and higher in Upcountry (1.8) and Dry Zone (2.2) types. The reason for the inhibition of laterisation with altitude is the decrease in temperature and the attendant retardation of mineral and humus decomposition, with possible translocation of Iron and Alumina; and with droughts upward leaching prevents desilication.

The recent classification of soils based on the theory that (Panabokke) podsolisation occurs in Ceylon is absolutely without foundation or reason; it must be dismissed as an effort at being novel. Joachim too falters here. This is to be expected if chemical analyses alone are used in classifying soils.

Conclusion: The development of Ceylon soils is influenced by the components of the environment; parent rock, climate, topography, vegetation and animal life. At different times and under various conditions one or another component plays a predominant part (usually climate) to give the different types of soils found in CEYLON as in the other parts of the world.

SOIL CLASSIFICATION

Degree of leaching *	Substances	Typical climate	Dominant Natural Vegetation	Soil type **
Fully leached	Raw humus absent(Mull)	Hot Wet Tropical	Rain Forests	Strongly lateritic
		Cool Wet Montane Tropical	Montane Rain Forests	Weakly lateritic
	Raw humus present(Mor)	Cool Wet Montane	Grasslands	Weakly lateritic Raw Humus soils
Incompletely leached	Limestone absent	Hot Dry Tropical	Monsoon Forests	Red Earths
	Limestone present	Hot Arid Tropical	Monsoon Scrub jungle (with lime-loving plants)	Calcic Red Earths
Unleached		All Tropical climates	All types corresponding to climates.	Alluviums
Impeded	Soluble salts abundant.	Hot Arid Tropical	Halomorphs and Mangroves	Saline
	Soluble salts in usual amounts.	All Wet Tropical climates.	(Reed-Sedge swamps)	Peats

** Any of these soil groups may be waterlogged, at the same time, but only partially.

* Leaching must be distinguished from mere percolation of water. (see Chapter 2).

THE VEGETATION OF CEYLON (SOILS)

The Natural vegetation of Ceylon reflects faithfully the differences in the various soils found in this island; that is, it bears a close relationship to the different soil types found in Ceylon. In fact a study of the vegetation can reveal what type of soil could be found in association. Even Agricultural and Plantation crops follow a pattern in keeping with that of the various soil types in Ceylon.

The vegetation of the Strongly Lateritic soils: These soils are found in the Hot Wet Lowland Tropical and the Warm Wet Upland Tropical climates (middle elevations), of Ceylon.

The natural vegetation of these soils are generally lofty Jungles of the Tropical Rain Forest types.

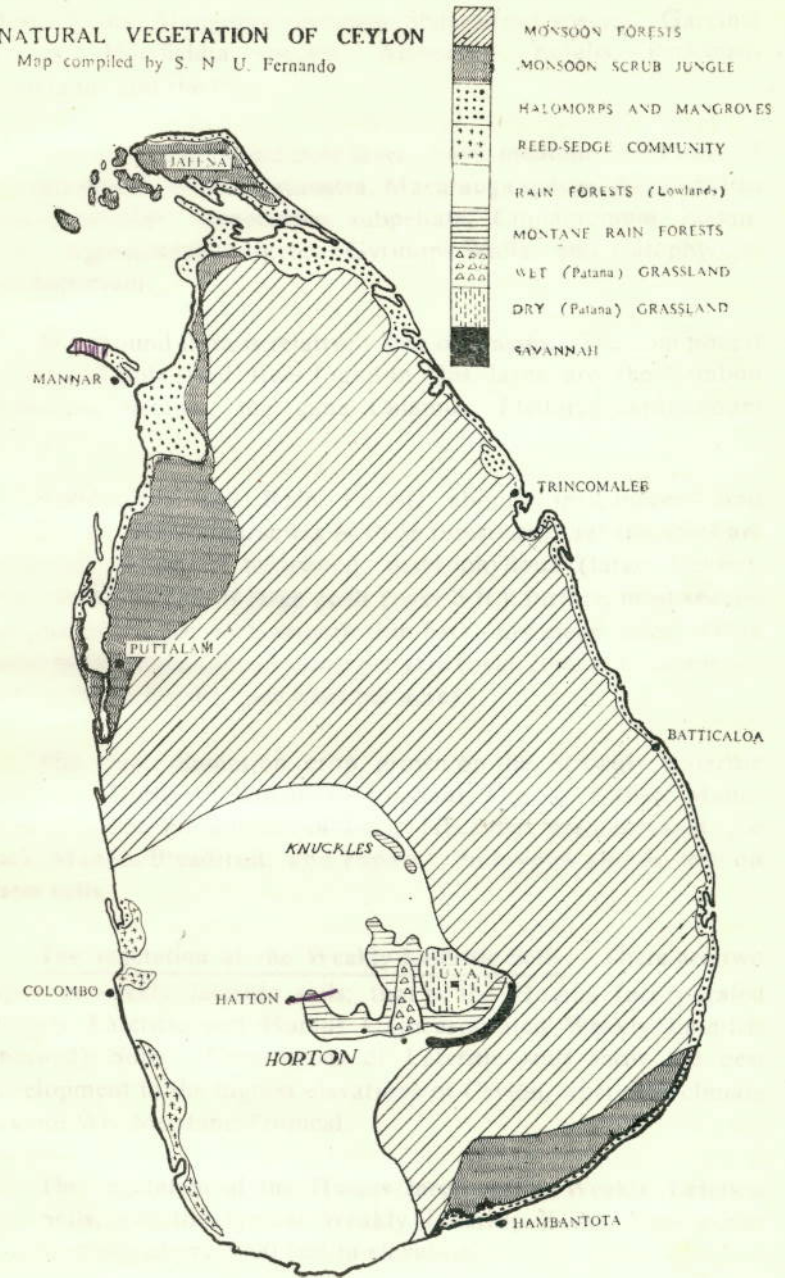
These forests are very tall (over 90 feet), multistoried, and floristically very rich, (over 100 species in a locality generally). These skyscraper forest are evergreen and lush.

The tree layers are arranged in Strata or Height Classes or Layers; hence the term Multistoried. This merely means that the forest is Stratified. There is usually a **canopy layer** above which trees often emerge to give an additional **emergent layer**. Below these two layers are **sub-canopy** layers of medium sized trees and **poles**. Finally, the ground flora form the lowest strata. Barring the ground flora, at least three tree layers can be seen (3 storied).

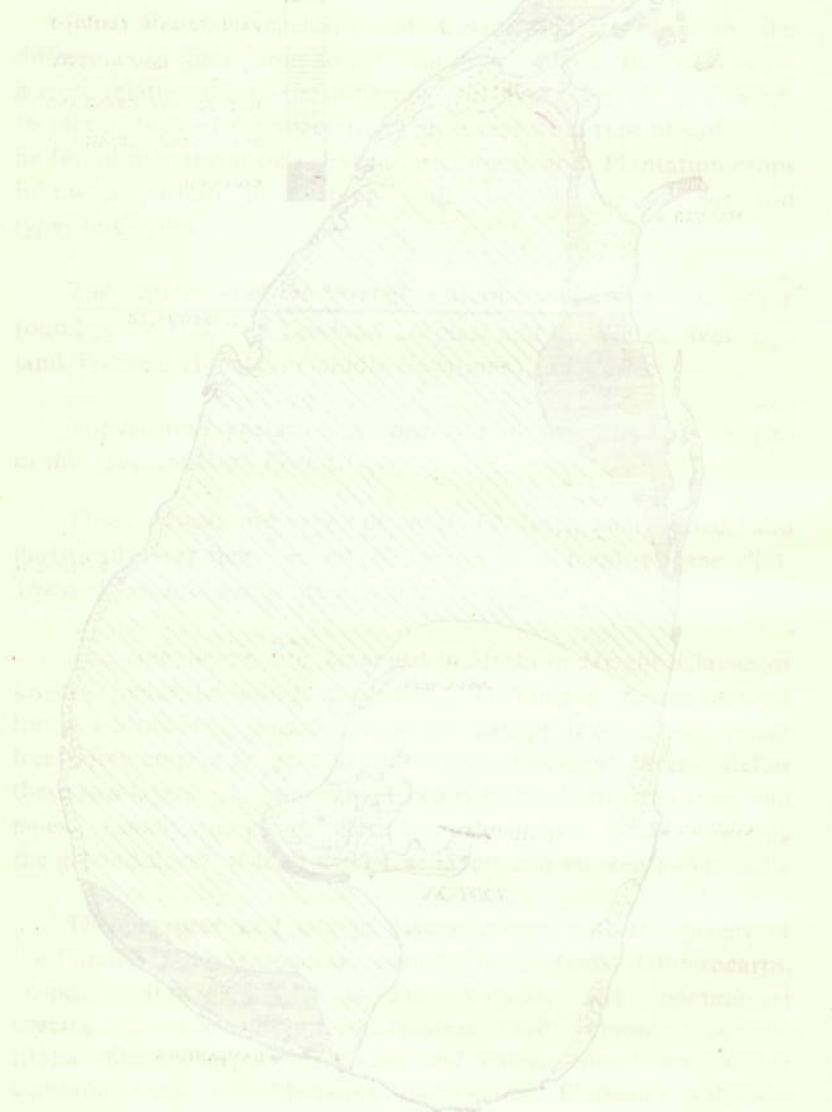
The **emergent** and **canopy** layers abound with the genera of the Family Dipterocarpaceae, namely the Doonas, Dipterocarps, Hopeas Shoreas, Vaterias and Vaticas. The commonest species of these Dipterocarpaceae are *Doona congestifolia*, *Dipterocarpus zeylanicus*, and *Vateria copallifera*. Other common trees are *Myristica dactyloides*, *Kurrimia zeylanica*,

THE NATURAL VEGETATION OF CEYLON

Map compiled by S. N. U. Fernando



THE VEGETATION OF WEAKLY LATERITIC SOILS



Cullenia excesa, Palaquium grande, Chaetocarpus castonocarpus, Mesua ferrea, Mangifera zeylanica, Semecarpus species, Garcinia species, Horsfieldia species, Artocarpus nobilis, Pericopsis mooniana and the like.

The sub - canopy and pole layers have medium sized trees of Dillenia retusa, Wormia triquetra, Macaranga species, Anisophyllea cinnomomoides, Semecarpus subpeltata, Cinnamomum zeylanicum, Agrostistachys species, Gyrinops Walla, and Calophyllum pulcherrimum.

The ground flora is relatively free of grasses. The commonest shrubs and pole sized trees found in this layer are the bamboo Ochlandra stridula, the cane Calamus, Elettaria cardmomum and others.

Besides this the Rain Forests abound in Climbers and Epiphytes. Other characters of these forests are that the trees are invariably fluted or buttressed, macrophyllous (large leaved), non - deciduous and of large girth (over 5 ft.): further, most species are phanerophytes, with smooth thin bark, and clean boles. These forest have a high cubic volume per acre (over 2000 c. ft. common) but have low density (few trees per acre).

The chief plantation crop grown on the Strongly Lateritic soils are Rubber, Cinnamon, Coconut, Cocoa, Coffee, Mahogany and a certain amount of Tea. Trees that are cultivated are Jack, Mango, Breadfruit, and Papaw. Pineapples also do well on these soils.

The vegetation of the Weakly Lateritic Soils: There are two types of weakly lateritic soils; that is, the Humus Incorporated Weakly Lateritic and Humus Unincorporated Weakly Lateritic (burned) Soils. These types of Lateritic soils show the best development in the highest elevations of Ceylon, where the climate is Cool Wet Montane Tropical.

1. **The vegetation of the Humus Incorporated Weakly Lateritic Soils,** (or the typical Weakly Lateritic Soils); they occur typically above 5000 feet in elevation.

In contrast to the vegetation of the strongly lateritic types the primeval forests of these soils are stunted (height less than 30 feet), one-storied, and floristically poor (only 40 species in a locality.) These forests too are evergreen. They are called **Montane Rain Forests**.

The trees in it are arranged in one story consisting of *Calophyllum walkeri*, *Syzygium umbrosum*, *Syzygium rotundifolium*, *Symplocos loha*, *Acronychia pedunculata*, *Euodia roxburghiana*, *Cinnamomum ovalifolia*, *Eleocarpus montanus*, *Actinodaphne speciosa*, *Litsea* species, *Neolitsea fuscata*, *Glochodion montanum*, *Aporosa* species, *Symplocos* species and many others. Below this is the usual ground flora of dwarf bamboo (*oxytenanthera* and *teinostachyium*), *Stobilantes* species, *Stenosiphonium* species and *Webera montana*. The giant *Dipterocarpaceae*, which dominate the vegetation of the Strongly Lateritic soils are rare or absent here, but in contrast the *Syzygiums*, *Calophyllum*, *Lauracea*, *Tiliacea* and *Symplocos spicata*, rule here. These trees are all of small girths usually less than three feet around.

These montane rain forests also abound in Epiphytes though Climbers are fewer. Other distinctive characters of these forests are that the trees are not fluted or buttressed, microphyllous (small leaved) thin barked, dwarfed and gnarled. Phanerophytes are fewer in these forests in contrast to typical Rain Forests. These forests have a very low cubic volume per acre (less than 500 c. ft. per acre), but the density is very high (over 3000 stems per acre). The trees in these jungles are badly adapted to the climatic conditions that prevail in the Weakly Lateritic Zone.

But when these areas are planted with sub-temperate trees of Eucalypts they grow to enormous heights here; so do Pines, Cupresses and Aurocarias. However, these sub-temperate types are not endemic to Ceylon. In fact there is no temperate flora occurring naturally in the tree layer of these forests. True temperate type trees do not regenerate and establish themselves **naturally** here, since these lateritic soils do not seem right for them, though the climate is to some

extent. This may be one reason why temperate trees are absent in Ceylon; that is, they may not be able to establish themselves on lateritic soils.

Cultivations and Plantations are not common on these soils. An extent has been cleared and planted with tea.

2. The vegetation of Humus Unincorporated Weakly Lateritic Soils: These soils occur in the Warm to Cool Montane Tropical Climates of Ceylon. In all these soils Grasslands are the dominant vegetation. These Grasslands are formed as a result of **continual burning**. (all Grasslands in Ceylon are formed consequent to burning).

(a) In the very cool zone above 6000 feet in elevation the raw humus layer is thickest and here **Wet (Patana) Grasslands** are found. These Grasslands have scattered trees of *Rhododendron* growing on them. The dominant grasses that are found here are tussocky perennials of *Chrysopogon*. Other grasses such as *Themeda*, *Pollinia* and *Arundinella* also occur. The bracken *Pteridium* is not uncommon in them. The Wet Grassland areas have no droughts. These soils are now cultivated with vegetables, mainly cabbage, leeks and potatoes. Plantations of Eucalypts and conifers are also common.

(b) Below 6000 and above 3000 feet, in the middle elevations of Ceylon, where the climate is drier and slightly warmer, the raw humus layer is thinner and here **Dry (Patana) Grasslands** thrive. The dominant grasses in them are the *Cymbopogons*. *Chrysopogon*, which dominate the Wet Grasslands, is rare or absent in them. Other grasses present are *Themeda*, *Heteropogon*, *Ischaemum*, *Arundinella*, and *Digitaria*. The ferns *Pteridium* and *Lycopodium* are also associates. Herbs of *Desmodium*, *Elephantopus*, and *Leucas* also predominate.

They are cultivated with vegetables such as cabbage, carrots, leeks, raddish, and potatoes. In certain areas tobacco is cultivated. The trees that grow well on these grasslands are Eucalyptus and Acacias.

(c) At the lowest elevations of the Dry (Patana) Grasslands (around 2000 ft.) scattered trees are found with the grasses. These areas suffer from short periods of drought and they get less available rain (owing to high evaporation) than Wet Grasslands. Two grasses *Cymbopogon* and *Imperata* dominate these Savannahs forests.

The tree species that are present in these are *Careya arborea*, *Phyllanthus emblica*, *Terminalia belerica*, *Anogeissis latifolia*, *Grewia tiliifolia*, *Terminalia chebula*, and *Diospyros melanoxylon*.

The raw humus layer in these soils is very thin indeed when compared to that in the Wet (Patana) Grasslands. These Forests are called **Savannahs**. These Savannah forests are commonest around 2000 foot elevations. These forests are short (canopy 30ft.). one-storied, and floristically very poor (about 10 species generally). Further, the trees are scattered. The Savannahs are not cultivated.

Therefore, it is observed that with increasing altitude, in areas subject to continual or periodic burning (human interference), the raw humus layer gets thicker and thicker (correspondingly laterisation gets weaker and weaker) and accompanied by this, the vegetation changes from Savannah forests at the lowest elevations (around 2000 ft.), to Dry (Patana) Grasslands in the middle elevations (around 4000 ft.), and to Wet (Patana) Grasslands at the highest elevations (over 6000 ft.). Hence, even the type of grasslands change with altitude in Ceylon, just as in the case of the forests.

It should be noticed that these Raw Humus Weakly Lateritic soils are maintained by repeated burning in the grasslands and savannahs (biotic factor predominates). If this burning is stopped, these grasslands will be gradually converted to forest vegetation, and the raw organic layer will disappear giving Humus Incorporated Weakly Lateritic Soils, or typical Weakly Lateritic soils.

The vegetation of the Red Earths: The soils occur in the Hot Dry Tropical Lowland climates of Ceylon (including Arid).

1. The natural vegetation of this climatic region is the typical **Monsoon forest**, adapted to partial drought conditions.

These forests are moderately tall, (60 to 70 ft.) multistoried and floristically poor (when compared to typical Rain forests, and they have about 50 species in a locality).

The most distinctive character in these forests is that there is a high proportion of **deciduous** species, so that they are semi-evergreen. Some trees shed their leaves during the drought. These forests are primary (and not secondary types formed as a result of burning, as some think), adopted to drought conditions.

The trees as usual are arranged in strata. There is a **canopy** layer of *Chloroxylon swietenia*, *Diospyros ebumum*, *Hemicyclia sepiara*, *Syzygium cumini*, *Berrya cordifolia*, *Pterospermum canescens*, *Vitex pinnata*, *Alseodaphne semicarpifolia*, *Adina cordifolia*, *Mitregyna parvifolia*, and the like, Emergents are few or absent. There is an abundance of *Ficus* species too.

Below the canopy is the normal **sub-canopy layer** of *Cassia fistula*, *Nephelium longana*, *Cassia marginata*, *Sapindus emarginatus*, *Cassia siamea*, *Gleniea zeylanica*, *Aphania bifoliatus*, *Grewia polygama*, *Bauhinia recemosa*, *Pleurostyliia opposita*, *Bauhinia tomentosa*, *Zizyphus xylopyra*, *Pityranthe verrucosa*, and others. *Hemicyclia* and *Nephelium* constitute 40 percent to these forests.

The ground flora has a fair amount of grasses. Other species associated with the grasses are *Glycosmis pentaphylla*, *Maba buxifolia*, *Mallotus philippinensis*, *Murraya clemiei*, *Memecylon umbellatum*, and *Webera* species.

These Monsoon forests are hence two layered (**two storied**). Climbers and Epiphytes are fewer than in the Rain forests. Though fluting is common in the Monsoon forests, buttressing is less frequent. There are fewer macrophyllus species than in the Rain Forests. Most species have smooth thin bark but the boles are not so cylindrical and long as in typical Rain forest trees. The trees are of smaller girth too.

These forests have less cubic volume content than the Rain forests but the density is about the same.

2. In the driest regions of the Red Earth Soils in the **Arid zone**, where the droughts are over 6 months of the year, the typical Monsoon forest change into a thorny **Scrub Jungle** with few trees. The Trees that survive from the typical Monsoon forests are *Hemicyclia sepiara*, *Manilkara hexandra*, *Maba buxifolia*, *Glenia zeylanicus*, *Bauhinia recemosa*, *Zizyphus xylopyra* and *Ferronia elephantum*. Most of these trees are thorny. All trees are dwarfed.

The ground flora too is very thorny. Common species in this strata are *Acacia eburnea*, *Crataeva roxburghiana*, *Hesperethusa crenulate*, *Azima tetraacantha*, *Webera* species, *Mallotus philippinensis*, and *Glycosmis pentaphylla*. Grasses too are more abundant.

These Scrub Jungles are one-storied, dwarfed (canopy 30 ft.), and floristically very poor. They have most of the characters of typical Monsoon forests, but to a lesser degree.

Therefore, the effect of Aridity in Ceylon is similar to that of Altitude (where temperatures are lowered); that is, with increasing aridity (and droughts) the forests change from tall, multistoried, and floristically rich forests, to, short, one-storied, and floristically poor types. Further, with aridity it is the thorny species that take precedence. Cubic volumes per acre also decrease accordingly. The density of these forests is very low unlike in Montane Rain Forests. The soils too have little humus.

These Red Earth soils are cultivated during the rainy seasons. Permanent cultivations are possible only with the help of irrigation. Paddy is the commonest crop grown in these soils. Sugar cane too is grown under irrigation. Trees that are popularly grown in these soils are Teak, Casuarina, and Cadju.

The vegetation of the Calcic Red Earths: These soils occur in the North - West corner of Ceylon and Jaffna, with the climate bordering on the Hot Arid Lowland Tropical.

The natural vegetation is the usual Monsoon Scrub Jungle found also in the typical Red Earth region, but with an abundance of Lime-loving species such as *Azadirachta indica*, *Tamarix gallica*, *Cassia Auriculata*, *Borassus* and *Phoenix*.

These Calcic soils are intensively cultivated in Jaffna. The usual crops grown are paddy, chillies, tobacco, and the like. Cultivations are usually done in the Monsoon rains; permanent cultivations are possible by digging wells into the waterbearing limestone rock and then using pump irrigation.

The vegetation of the Alluviums: The Alluviums are found in most of the climatic regimes of Ceylon and they possess the vegetation associated with them. The Alluviums are absent in the Limestone districts of Northern Ceylon, since rivers cannot flow over these rocks. The alluviums of the Wet Zone have Rain Forests while that of the Dry Zone have Monsoon or Scrub Jungle. ~~With riverine coniferous trees like *Terminalia* and *Morinda*.~~
The Alluviums make the best agricultural land in the country. They are intensively cultivated in the Wet Zone (mainly with paddy) and in the Dry Zone by using irrigation.

The Vegetation of Saline Soils:

1. The natural vegetation of saline soils are halomorphic plants, (salt-loving). Saline soils near the sea and in **temporarily water-logged areas**, have a creeping type of vegetation of *Ipomea biloba*, *Hydrophylax maritima*, *Lippia nodiflora*, *Herpestis monniera*, *Emilia sonchifolia*, *Sesuvium portulacastrum*, *Petalium murex*, *Agyneia bacciformis*, *Euphorbia rosea*, *Canavalia podocarpa*, *Crotolaria maritima*, *Spinifex littoreus*, *Cyperus arenarius*, and *Indigofera* species. A few shrubs, namely *Pandanus tectorius*, *Opuntia*, *Calotropis gigantea*, *Sueda maritima*, and *Jatropha* species may also be present. Common tree species found are *Calophyllum inophyllum*, *Hibiscus tiliaceus*, *Barringtonia* species, *Coconut*, *Salvadora persica*, *Sapium insigne* *Thespesia populnea* and *Acacia planifrons*.
2. Salt marshes are **saline swamps** found on tidal flats, mouths of rivers, backwaters and mud flats. These salt marshes are **permanently waterlogged** and they possess a type of vegetation

called **Mangroves**. Mangroves are salt marsh plants of Rhizophora, Brugiera, Avicennia, Ceriops, Sonneratia, Lumnitzera, Aegeceras, Nipa fruticans, Salicornia, Sueda and others. Most of these plants have viviparous germination and adventitious breathing roots. These aerial breathing roots are called pnematophores.

These Mangrove forests are short (about 20 ft.), single storied and floristically very poor, when compared with the Monsoon and Rain forests.

These saline soils are toxic for normal plant growth.

The Mangrove swamp soils are not cultivated. However, the drier Saline soils are planted with coconut, palmyrah and other palms, especially those earths formed by wave deposits on the coasts of Ceylon.

The Vegetation of Peats: The vegetation consists of **Reed - Sedge Swamps**. Peats too like saline soils have specialised types of plants living on them. The most common flora on Peats are Cyperus, Eriocaulon, Juncus and grasses. In Lowcountry Peats, other amphibious plants, namely, Lasia spinosa, Susum, Polygonum, Jussiaea, Acorus, Aeschynomene, Typha, and Terminalia arjuna are also very common. Peats too are not cultivated unless they are drained.

The peats of the Upcountry consist mainly of Cyperus, Eriocaulon, Juncus, and broad bladed grasses of Garnotia, and Sphagnum Moss.

In General: Thus, the soils have a dominating influence on the pattern of vegetation in Ceylon; both in turn are affected by the climate. Other factors, namely geology, topography, and the biosphere, are no less significant.

The close connection between the vegetation and the soils in Ceylon could be used in mapping and identification. A study of the natural vegetation is absolutely essential for those interested in the pursuance of soil studies. A soil cannot be studied by itself

alone; the whole complex components of the ecosystem (and its influence and actions), in which soil occurs, must be perused. To know one's soils an integrated knowledge of the whole of natural Ceylon (geology, climate, vegetation etc.) is necessary. That is, to learn the Island soils one has to study Ceylon itself.

Conclusion: It is evident that the correlation between the soil and natural vegetation is very close in Ceylon; and they reflect faithfully differences in the soil conditions. All previous classifications of Ceylon soils (Panabokke and Joachim) which admit that podzolisation occurs in this island are not tenable. Ceylon does not have the right climatic conditions for such a process to occur.

SOME ADVERSE CONDITIONS IN THE SOIL

Deficiency of incorporated humus; or the presence of unincorporated humus.

Leaching and loss of nutrients.

Too high a content of sand or clay.

Compaction of the soil and cementation.

Lack of water.

High ground water table.

A widely fluctuating ground water table.

Low or very high temperatures in the soil (e.g. frost).

Unsuitable soil reaction; may be too acid or alkaline.

Bad soil structure; absence of crumb structure in particular.

Presence of toxic substances, for example ferrous iron, sulphides.

Shallow soils.

Geological rocks yielding poor raw materials; e.g. underlying quartzite.

Absence of organisms, especially earthworms.

Erodible soils.

Hardpans, indurated soils.

Salinity and salt incrustations.

Treatment of soils: Adverse soil conditions must be diagnosed correctly and one or more of the following treatment processes may be tried, if appropriate.

Addition of organic matter, and fertilisers: Application of these fertilisers is based on empirical experience.

Liming: This process is very useful on acid grasslands, particularly on those with a thick mat of undecomposed humus. The lime will increase micro-biological activity by reducing the acidity, and the mat may disappear. Liming reduces compaction too.

Drainage: Badly drained soils can be drained by a system of drains.

Tilling, Hoeing & Ploughing: Here the upper layer of soil is turned over. The result is that organic matter gets buried and incorporated into the soil; heavy clayey soils may be made more friable too; percolation of water is facilitated in poorly drained soils; the soil is made porous too. Ploughing and hoeing and furrowing can also break up hardpans and gravelly sub-surface layers, and any kind of cementation.

Bare Fallowing: The practice of leaving land uncropped and bare for a season or period is called fallowing; it helps degraded soils to revitalise and recover.

Peat: Peat may be added to very alkaline soils to reduce the toxic alkalinity.

Burning: Certain very acid soils with mats of peat on them, are favoured by burning. Burning is not recommended otherwise, especially in soils subject to erosion.

Grazing: This must be stopped on erodible soils as it tends to remove the vegetation that fixes these unstable soils, compaction occurs too.

Trenches and contour planting: Soil erosion and run-off of water can be arrested by these methods. In contour planting the crop is planted very closely spaced, along the contour lines. Gently sloping trenches and drains also stop accelerated erosion by acting as silt pits, if dug along contours.

Cover crops: Cover crops may be grown to stabilise soils and to increase the total nutrient capital of infertile soils. The best cover crops are legumes for they give highly nitrogenous residues. They also insulate the soil against strong insolation by shading.

Removal of Salinity: Saline soils may be improved by scraping any salt incrustation, and by addition of Gypsum (the Ca replaces the Na.) or Sulphur.

Shading: Generally trees are the best to provide high shade. Legumes are good to provide low shade as they give Nitrogen too. Shading of soils is an important practice in the Tropics where soils are subject to strong insolation. But it must be remembered that certain plants do not grow under shade; they are called light demanders.

RESUME

Ceylon soils are formed mainly by the process of chemical weathering and leaching. Most of the soils are formed over non-limestone rocks of very similar characteristics; in these soils climate plays a dominant role in soil formation. Over the limestone areas geology also plays a modifying role.

The most destructive soil forming process in Ceylon is laterisation: Altitude (temperature), aridity (droughts), and humus, can halt or retard laterisation by different methods wherever it occurs. Therefore, the removal of any (humus) natural vegetative cover must not be done without forethought. Another danger in Ceylon is soil erosion, especially in the Upcountry. Here too, vegetation prevents erosion.

The best soils in Ceylon, from the point of view of agriculture, are the Wet Zone Alluviums. The Dry Zone Alluviums are good too but they require irrigation. The worst soils in Ceylon are the Saline soils for they are toxic to normal plant growth. But even the worst soils can be utilised by proper management. For example, Peats can be drained and brought under cultivation. Further, most soils are deep, well-drained, porous, crumbly, friable and moist, and so ideal for plant growth.

In general, Ceylon soils show favourable soil reactions on the side of acidity. The majority of the soils display *ph* values quite satisfactory for normal plant growth. Soils of extreme acidity (peats) and alkalinity (saline soils) are only of restricted occurrence. The soil reaction bears a close relationship to climate; these soils of the Wet Zone are acidic, and those of the Dry Zone are nearly neutral, while those of the Arid regions are alkaline.

Soil temperatures are very satisfactory in Ceylon for tropical flora, and range around 80° F. Soil temperatures are unfavourable for tropical flora only in the highest mountains over 6000 feet; Here at 57° average, temperate trees thrive, if introduced, but they do not occur naturally.

The climate in Ceylon generally aids speedy decomposition of rocks, minerals, and organic matter. Organic matter is decomposed as rapidly as it is formed, but it is turned over speedily between the soil and plants living on it. If vegetation is absent the humus and other nutrients are generally leached rapidly and lost, except, in bogs, and in low temperature areas, where decomposition is retarded. The fertility of Ceylon soils depend on rapid decay and quick turnover.

Most Ceylon soils show latent deficiency of plant nutrients, both organic and mineral.

The organic matter content (and Nitrogen) is low for reasons given before; this being the principal capital of plant food it makes the soils intrinsically poor, in nutrient elements. But plants can thrive on this small capital of nutrients by quick utilisation and turnover. Rapid chemical weathering of rocks too aids this process.

The natural vegetation of Ceylon bears a close relationship to the soil type with which it is associated. The effect of lowered temperature (increasing altitude) and increasing aridity on vegetation, is alike in some respects; that is, forests change from tall, multistoried, and floristically rich forests to dwarfed, one-storied, and floristically poor types.

Ceylon is basically agricultural, depending on the soils for its sustenance. The soils, therefore, are one of our greatest assets.

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