LAND CLASSIFICATION IN CEYLON WITH REFERENCE TO BASIC CONDITIONS OF SOIL AND WATER CONSERVATION *

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LAND classification for purposes of soil and water conservation is very complex in view of the fact that it goes beyond a simple objective classification of physical factors such as geology, soil, topography, steepness of slope, climate, vegetation cover, &c., but includes such human factors as patterns of agriculture, sociology and economics. For effective conservation it is necessary to carry out surveys of all these factors in great detail and in very small units such as individual farms or estates, the final result being a Land Use or Land Capability Map.

The contribution we as geologists can make to such a classification is to provide as far as possible the basic physical factors of environment with which we are familiar in the course of our normal routine work. The significance of land use or rather land misuse in causing deterioration and loss of soil and water has been brought out very strikingly in a recent study of major land slip areas of the Island. However, this aspect of the land is a specialised study requiring special techniques of investigation and is a function of the Soil Conservationist. The classification which is proposed is based mainly on the physical environment and leaves out this important aspect of the land.

The processes of normal geological erosion are well known and will not be considered now. These are natural processes which take considerable ages of time, but can be accelerated by human agencies to cause sudden loss of soil and water. The basic facts which we are concerned with are soil and water in the land. It is generally accepted that almost all water on the surface of the land and in the ground beneath is derived from precipitation in the form of rain, snow and ice, and almost all the soil is derived from the parent rock material under the action of the various pedogenic agents.

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In Ceylon precipitation is essentially in the form of rainfall which varies from 50 in. per annum in the north-west and south-east parts of the Island of the lowland zone to over 200 in. in the south-western slopes and the hill country. The central highland zone is about 100 in. and the remaining portion of the lowland zone 50 in. to 75 in. The mean rainfall of the Island is about 80 in. per annum.

Crystalline rocks of pre-Cambrian age occupy nine-tenths of the Island's surface. These comprise in the main a series of Gneisses—the Vijayan Gneisses and the Khondalite Group of Rocks which consists of intensely metamorphosed sediments of pre-Cambrian age and show a great variety of lithological types. Associated with the Gneisses and the Khondalite rocks are the Charnockite series of hypersthene-bearing granties and a less extensive pink Tonigala granite of the north-western part of the Island and coarse-grained, pegmatitic granites younger in age.

These rocks have been folded into a complex northward pitching synclinorial axis striking in a north-north-west to a south-south-east direction through most of its length, and has had a very marked effect on the erosion pattern of the Island and its topography, ridge and valley coinciding with the structural trends.

With the exception of a fragmentary representative about a square mile in extent of Upper Gondwana Age occurring in the Tabbowa area, there is a lack of younger formations until Miocene times. Miocene rocks consisting of fossiliferous limestone occupy an area of 800 square miles and occur in two widely separated areas. The Kudremalai-Jaffna series is in the north-west of the Island and a very small deposit occurs in the extreme south-east, in the Yala area.

The Pleistocene and Recent deposits are from the point of view of soil and water conservation the most important formations of the Island. Their distribution is shown in the soil map which is a simplified sketch of Dr. Joachim's Provisional Soil Map of the Island (Joachim 1945). The crystalline rocks of the south-west are capped by varying thickness of laterite derived from the decomposition of the underlying granites and gneisses, under the prevailing conditions of temperature and precipitation. The alteration of the crystalline rocks in the dry zones of the south-east and north-east has resulted in the formation of a lateritic earth.

Intermediate in age between the Pleistocene laterite and Sub-Recent and Recent deposits of river alluvium, littoral sandstone and beach sands, there occurs in well defined but inconstant horizon a well rounded gravel mixed with red earth—the "Post-pliocene gravels." These occur in the north-western and northern parts of the Island in a few isolated and widely separated patches, in the area shown in the

Geological sketch-map as a continuous formation. The thickness varies from 8-10 feet though some 40-50 feet thickness has been known to occur in mounds to the north of Anuradhapura.

The intimate relationship between land and water is clearly brought out in nature's water cycle. The rain falling on the land is disposed of as direct run-off, evaporation and transpiration from vegetation, evaporation from free water surfaces and soil and seepage into the ground to augment the water table.

The proportion of the rainfall available for direct run-off is the residue after the demands of percolation, evaporation from the soil, surfaces of water and vegetation (including transpiration and evaporation of rain water intercepted by foliage) have been satisfied.

The mean annual rainfall for the Island is about 80 inches or about 107 million acre-feet; Abraham (1946) estimated the total run-off from the Island as being 27.5 million acre-feet or about 25 per cent. of the mean annual rainfall.

The Administrative Report of the Director of Irrigation for 1952 contains data on the annual river flow measured at over 50 complete gauging stations in the main catchment areas of the Island, over a period varying from 6 to 28 years.

Ten gauging stations in the "Wet Zone" had an annual run-off of 71 per cent. to 84 per cent. of the rainfall, with one station over 100 per cent.

Ten stations located in the Humid Zone had a run-off from 47 per cent. to 67 per cent.

Out of twenty-seven stations located in the Dry Zone eighteen had a run-off from 25 per cent. to 47 per cent. and nine had from 12 per cent. to 22 per cent.

There is very little information available on the analysis of river flow into its main components, surface run-off and ground water run-off. The magnitude of these components will depend on the nature of the catchment basins, particularly the depth, permeability and storage capacity of the soil and underlying rock and the character and distribution of the rainfall.

The discharge curve of some of the larger rivers of the Island can be seen to consist of several irregular peaks separated by short stretches of uniform base flow. This is to be expected from the geological make-up of the Island—the lack of rock formations capable of storing large quantities of ground water.

Normal monsoonal rainfall is more or less evenly distributed in most parts of the Island. Thunderstorm and cyclonic rains are generally

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characteristic of the inter-monsoon periods. Thunderstorm rain fortunately occurs with great intensity in the dry lowlands. For instance, some maximum intensities that have been recorded for the Island are—

Mullaitivu	..	31.18 inches in 24 hours
Nitre Cave	..	24.78 inches in 24 hours
Chavakachcheri	..	21.17 inches in 24 hours
Jaffna	..	20.48 inches in 24 hours
Colombo	..	11.40 inches in 24 hours

Heavy storms of this nature when they occur in the highland zone can cause severe damage to the land such as the storms of 14th and 15th August, 1947, when rainfalls of 17 to 35 inches in 48 hours were recorded. These storms caused peak discharges of 242-276 cusecs per sq. mile in the Kelani catchment and 390-450 cusecs per sq. mile in the Mahaweli Ganga upland catchment—the largest flood discharges recorded since 1870.

The nature of the rainfall and the relief of the land are thus conducive to a rapid run-off with consequent loss of top soil—this loss of soil and sub-soil mean that underground sources dwindle, as the soil is the most important carrier of water in the Island.

Areas where the precipitation is in excess of evaporativity* the magnitude of the excess will give an index of the effectiveness of precipitation, as the residual available for maintaining stream flow and for percolation to ground water will be greater. On the other hand where the precipitation is less than the evaporativity, the amount available for replenishment is small ; the magnitude of the deficit will give an index of aridity. On this basis the following "*Zones of Effective precipitation*" can be recognized :—

TABLE 1.—*Effective Precipitation Zones*

Moisture Zone	*Annual Rainfall*	*Annual Evaporativity*	*Annual Effective Rainfall*	*Annual Run off/ Rainfall Per Cent*
(A) Wet Zone	100 " to 200 "	34 " to 65 "	740 "	71–84
(B) Humid Zone	75 " to 100 "	60 " to 82 "	0–40 "	47–67
(C) Dry Zone	50 " to 75 "	70 " to 98 "	–40 "–0 "	25–47 12–22
(D) Arid Zone	less than 50 "	greater than 86 "	lessthan–40 "	0 to 12

"*Note* :—*Evaporativity,* or potential evaporation is definied by Meinzer (1923) as being "the rate of evaporation under the existing atmospheric conditions from a free surface of water that is chemically pure and has the temperature of the atmosphere."

Some values of evaporativity calculated for the Island on an empirical formulace are given in Table I.

LAND CLASSIFICATION

A tentative and broad division of the Island based on a combination of climate, topography, soils and geology is suggested as a basis of classification for soil and water conservation for the Island. Since these factors exert a major control on the mode of occurrence and flow of water in the soil and sub-soil the regions thus defined should possess a broad uniformity of character.

Five major divisions are proposed as follows :—

(1) The Wet Highland Zone,
(2) The Humid Upland Zone,
(3) The Dry Lowland Zone,
(4) The Miocene Limestone Zone of the North,
(5) The Coastal Zone.

(1) The Wet Highland Zone includes the zone with effective precipitation greater than 40 and a surface run-off from 70 in. to 160 in. per annum. The general elevation can vary from 3,000 ft. M. S. L. to over 8,000 ft. Geologically this zone is composed of the Khondalite group of rock referred to earlier. They are traversed by a well defined system of joint and fissure planes. The topography has been profoundly effected by the geological structure. The dominant feature of these systems of valleys is the presence of well defined scrap slopes with steepness in certain cases exceeding 80°. There is no continuous water table but there is a vigorous circulation of water in the joint and fissure planes of the rock as evidenced by the numerous springs that issue from them. The discharge from these springs can vary from over quarter of a million to half a million gallons per day.

The soil cover is mainly lithomargic or kaolinitic in character, the clay content being very often over 45-50 per cent. The depth of this soil cover is variable and extends in certain areas to over 100 ft. The presence of this kaolinitic material causes much instability and slumping when it is in a state of over saturation. The conditions which favour this fall broadly into two categories (*a*) conditions inherent in the areas and relate to geological, structural and topographical features over which man has no control, and (*b*) a set of conditions which have been imposed on the area by the activities of man.

The Kotmale and Ginigathena slipped areas are typical of this zone.

(2) The Humid Upland Zone—Geologically this zone is similar to the wet highland zone. The essential differences are its lower elevation, less steep topography and smaller effective precipitation. The dominant soil cover is laterite. A typical laterite profile shows

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a transition from partly decomposed gneiss through an intermediate zone of kaolin and angular quartz to typical vesicular and sectile laterite of high porosity and permeability. This is capped by a loose layer of ferruginous nodules immediately under the soil. Thickness of the laterite cover can in general vary from 40-50 feet.

The hard laterite can often support near vertical slopes but the soft laterite has a tendency to cave in when over saturated. There is a considerable oscillation of the water table during the year. The rise of the water table to its upper limit after a few hours of heavy rain is characteristic. Any excess rainfall tends to flow over the saturated ground and causes considerable amount of gully erosion.

(3) The Dry Lowland Zone—The rocks in the zone belong to the same types as in the highlands but there is here a more extensive development of the Vijayan Gneisses. As in the Highland Zone there is practically no continuous water table in the crystalline rocks. Numerous springs however issue from the fissures and joints of the quartzites and crystalline limestone and gneisses and yield from 15,000 to 50,000 gallons per day.

The laterite of the humid zone gives place in the dry zone to a friable mixture of quartz sand and ferruginous clay, which in turn gives place to a red and reddish brown earth in the drier parts of the zone. Occasionally a non-lateritic grey loam occurs in certain districts. The colloidal clay content of the dry zone soils is much lower in them than in the laterite of the humid zone, being only about 15-20 per cent. They are nevertheless derived from the same rock type their differences being due to the different climatic conditions governing their formation. As a result of the prevalent aridity in the area most of the rivers are dry during a part of the year and some areas are practically areas of internal drainage. This results in a retention of salts which would normally have been carried to the sea in solution by rivers, and accounts for the hardness of the water and the occurrence of concretionary nodules (Kankar) in layers of two or three feet in the sub-soil in certain localities.

The water from these areas will generally be high in mineral matter and hardness and possess a high degree of alkalinity.

Where the bed rock is irregular, basin shaped depressions of alluvial soil overlying a disintegrated rock provide good aquifers for the storage of ground water.

The Alluvium of the major river systems often store considerable amounts of ground water, that drains to the sea slowly as under flow. This water could be conserved for use.

The relatively low relief and thin soil cover, generally less than 40 to 50 feet thick in this zone, results in very meagre storage of water underground. A continuous water table occurs only for a short period after the rainy season. As the dry season progresses the water-table declines and towards the end of the dry season water is found only in isolated pockets of decomposition in the crystalline rock floor, or in areas where the water-table is artificially maintained by means of a tank or irrigation channel. Natural streams and water courses, except rivers taking their rise in the central hills, are reduced to a trickle or are completely dry during the dry season.

Under the prevailing climatic conditions the soil of the dry zone has a tendency to rapid destruction of the soil organic matter and consequent deterioration of its physical conditions rendering the soil open to vigorous erosion as a result of the torrential rains that fall upon this area. Varying agricultural practices from the earliest times have added to the impoverishment of the soil.

The development of this zone is progressing fast and it is very essential that effective measures should be adopted for conserving the soil and the water contained therein.

This zone also includes the portions of the two areas climatically coming under the " Arid Zone. " The processes of erosion are more intense than in the rest of the Dry Zone and have given rise to almost desert conditions where in addition to the erosive action of water we have erosion due to wind. The Desert Tracts of the North-West Arid Zone are well known and have been described by Wayland.

(4) The Miocene Limestone Zone of the North—The limestone is best developed in the Jaffna peninsula, which is entirely composed of it. The limestone varies from a somewhat cellular material full of coral to a massive rock in which gastropods are common. It usually weathers into a honey-combed mass. The soil cover is the bright red free-draining " Terra Rossa " from 1 to 8 feet thick. Sand dunes fringe the peninsula, particularly in the south-west, where spites or tomboli link it up with the mainland.

The surface of the land is comparatively flat rising in the north to over 30 feet M. S. L. The permanent level of ground water saturation is at sea level, the body of fresh water occupying a Gyben-Herzberg lens of depth about a 100 feet at the centre of the peninsula, floating on brackish water. There is a considerable amount of fresh water discharging from this lens to the sea in coastal springs.

While the problem of soil erosion is not so acute here, there is a need to conserve supplies of fresh water. This can be achieved by augmenting the amount of percolation into the ground by delaying surface run-off and by building dams to prevent the inroad of sea water into the low-lying lands and contaminating the fresh water table.

(5) The Coastal Zone is divisible into 5 well marked sub-divisions based on geological structure and the nature of the accumulated deposits. These are—

(*a*) *The Eastern coast* extending as a continuous belt from Hambantota to Point Pedro with the exception of a small stretch from Trincomalee to Kuchchaveli.

(*b*) *The West coast* belt stretching from Panadura to Puttalam with a maximum inland extension near Chilaw.

These are characterized by cumulative deposits of dune sand, beach bar, sand spit and lagoon deposits. These deposits are characteristic of a stationary or emegent coastline.

(*c*) *The North-west coast belt from Puttalam to Point Pedro*—This part of the coast is backed by Miocene Limestone rocks and gives rise to low cliffs that stretch from Kudremalai to the Jaffna coast.

(*d*) *The South-west coast from Panadura to Hambantota* is a typical drowned valley system cut off from the open sea by sand bars and is characteristic of a submerged coastline. The coastline is concordant and trends in a direction parallel to the structural strike of the hills which approach the sea and terminate in small promontaries and cliffs. This stretch of coast receives the full blast of the South-west monsoon and its form shows that it is being rapidly eroded.

(*e*) *The portion of the North-East coast from Trincomalee to Kuchchaveli*—The North-east coastal tract from Trincomalee to Kuchchaveli is discordant—the rocks striking athwart the coastline. Here too the rock rises steeply from the sea in cliffs like those found north of the Trincomalee harbour. This portion of the coast is actively acted upon by the North-east monsoon.

The coastal lowlands are a tract of country where vertical corasion is at a minimum as the base-level of erosion has about been reached. We are in the flood plain of rivers where lateral corasion and bank erosion with periodical flooding is predominant. These lands are attacked in two fronts from the land as well as from the sea. The full force of wave, wind and tidal currents has to be withstood in

addition to the erosive action of water flowing seawards from the land. The problem of soil conservation here is thus complex and the measures to be adopted should be of a different nature to that in the upland areas.

There is considerable storage of fresh water in the more permeable formations of the coast, floating as lenses or lenticular bodies on top of saline sea water. This delicate balance is possible so long as the fresh water body is able to maintain a head above sea level. This is accomplished by recharge from rainfall and infiltration from streams draining the main land. Excessive pumping from wells or the acceleration of natural drainage into the sea artificially, results in the encroachment of brackish water and gradual depletion of the fresh water stored in these formations.

The storage facilities in the coastal area is variable and the amount of water that can be withdrawn from the ground has to be determined carefully for each area, so as to conserve supplies of fresh water for human use. Artificial recharge of the water table by delaying run-off and increasing infiltration rate by improved soil management are some of the means that can be adopted to increase the storage of fresh water.

In the foregoing an attempt has been made to demarcate very broadly Basic Zones for purposes of soil and water conservation in the Island. This has been done by superimposing the geology, topography, effective rainfall and the soil of the Island.

The major zones so defined, should be capable of subdivision into regions according to detailed topography, depth, texture, and permeability of soils, slope characteristics and vegetation cover. The regions in turn should be capable of further subdivision according to land use and agricultural and farming practice, the farm or estate forming the unit to be used for this stage of the survey. In this manner it will be possible to build up the final survey of soil and water conservation of the land.