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NO. 28

SOIL AND SOIL CONSERVATION IN SRI LANKA

By

Mervyn W. Thenabadu

NATURAL RESOURCES ENERGY & SCIENCE AUTHORITY
47/5 MAITLAND PLACE
COLOMBO 7

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FOREWORD TO THE SERIES

The dissemination of scientific information is one of the main functions of the Natural Resources, Energy & Science Authority. The Journal of the National Science Council published by this Authority provides a medium for the publication of scientific research papers, and "Vidurava", the quarterly science bulletin contains scientific articles of a general nature which is of interest to the public.

There is still a wide gap in the availability of reading material on scientific subjects of local interest. One result of this is that science students confine their reading only to their school notes and to the few available text books which are mostly published abroad. In an attempt to improve this situation, the Working Committee on Science Education Research of the Natural Resources, Energy and Science Authority decided to publish a series of booklets on scientific topics of local interest as supplementary reading material for students and the general public. The authors who have been selected by the Committee to prepare these booklets are experts in their respective fields. The manuscripts that were submitted by the authors were examined by referees before being accepted for publication. The views expressed in these publications are those of the authors and are not necessarily those of the Natural Resources, Energy & Science Authority.

I must thank the Working Committee on Science Education Research of the Natural Resources, Energy & Science Authority, and in particular Prof. V. Basnayake who is the Hony. Director of the Working Committee for the work they have done to make this project a success.

R.P. Jayewardene
Director General

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PREFACE

Soil is our most valuable natural resource. It is claimed to be a renewable resource, but in terms of human time scales it is not. Hence it is well to be aware of its vital importance, its behaviour and its fate.

This monograph is pertinent mostly to the soils of Sri Lanka. It is broadly divided into two parts; soils, and soil conservation. It contains information obtained from publications, both local and foreign, and from personel communications.

The encouragement and help from friends, colleagues and superviors is gratefully acknowledged.

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May 1988

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FIGURES

PART I

SOILS

1. INTRODUCTION

Soils are natural bodies on the earth's crust. They have to be considered in three-dimentional perspectives, and are composed of minerals, organic matter and living organisms, with varying amounts of water or moisture and air occupyng the voids between the solid constituents.

Soils cover the landscape, and in Sri Lanka they are usually between 40 to 150 cm deep in most places. A very high proportion of all life on earth is confined to the upper layers of soil. The top soil, usually not more than 15 cm deep at most, supports our civilization.

The chemical, physical, and mineralogical properties of soils are the effects of the actions of climate and organisms on the parent materials of soils; the effect of which could be conditioned by relief over periods of time. The above mentioned properties are important to the soil's ability to store and supply nutrients for use of plants that they support and sustain.

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Like those of most wet tropical regions, our soils have both advantages and disadvantages. Agriuturally there are only a limited number of crops that cannot be grown here; from the coastal lowlands to the highlands; on the highly weathered acid soils of the wet zone or on the near neutral soils of the dry zone. However, to obtain maximum benefits these soils would have to adequately fertilized, and suitably amended where necessary. Thus a knowledge of soil chemistry can enrich these soils, although it would be costly. The nature of our soils is one of the factors that limit agricultural use of the land.

The parent material of soils is rock or any material originally derived from rock by the process of weathering. During this process complex compounds in rock minerals undergo changes. The soluble materials are constantly removed by the percolating waters. Organic matter on the soil surface, on decomposition liberates organic compounds which greatly increase the solubility of these complex compounds. Percolating waters, under such conditions, therefore, carry more dissolved materials. At the end, only rock fragments, most of which is inert quartz of little value to plants, remain. Because temperature increases the rates of chemical reactions,

improverished soils are formed more rapidly in the hot wet tropics than elsewhere. Thus tropical soils tend to become poor with age, and their rate of nutrient supply to plants become slower progressively.

2. THE SOILS OF SRI LANKA

Sri Lanka shares many geological characteristics with South India, because in geological times it would have formed part of the Indian sub-continent.

The island's total land area of 6.66 million ha, can be demarcated into three major climatic or agroecological zones.

(1) The wet zone of 1.54 million ha, which is confined to the south west quadrant of the island;

(2) The dry zone of 4.17 million ha which comprises the bulk of the island, and confined to the north east, north west and south east plains; and

(3) The intermediate zone of 0.85 million ha which lies between the dry and wet zones.

These three major zones are further subdivided into seven major agroecological zones on the basis of altitude and landform as depicted in Fig. 1.

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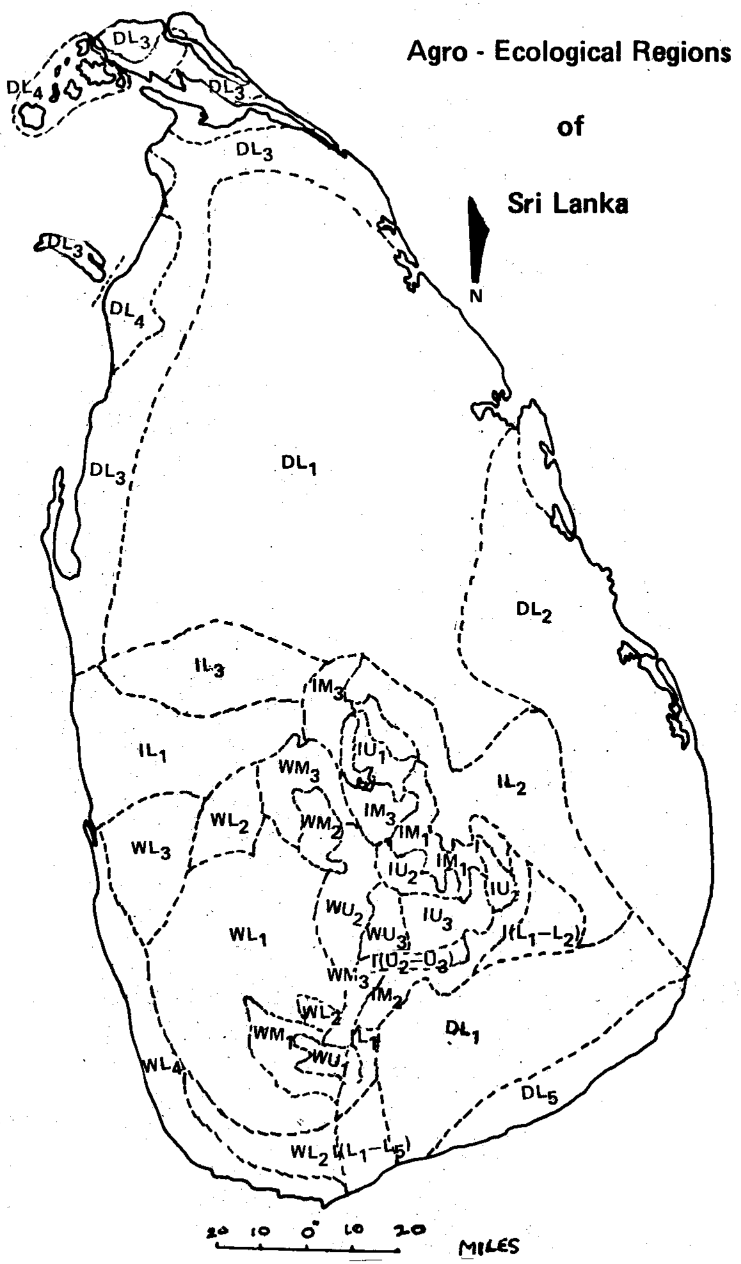

Fig. 1. The agro-ecological regions of Sri Lanka

On the basis of elevation the following three regions are recognized;

Region	Elevation above mean sea level (m)
Low country	0- 300
Mid country	300 - 600
Up country	> 1000

The whole of the dry zone is in the low country, where the land forms vary from flat to undulating. Land forms in the mid and up country vary from undulating to rolling, hilly and the steeply dissected. In some areas they may be even mountainous.

The seven major agroecological zones are further divided into 24 well defined agroecological regions, each region having unique combination of rainfall pattern, landform, temperature range, elevation and soil depicted in Fig. 1, and Table I summarizes the salient information.

Every soil in Sri Lanka has a unique profile. Where a soil profile is exposed as in road-cuts, wells or burrow pits the various layers or "horizons" could be observed and identified. The predominant soil in an area is related to the climate, parent material, plants and animals, slope or topography, and to time needed for soil formation.

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Table 1 **Rainfall expectancy values of the agro-ecological regions of Sri Lanka and their associated soils and terrain**

ZONE	AGRO-ECOLOGICAL REGION	SYMBOL	75% EXPECTANCY VALUE ANNUAL RAINFALL (inches)	MAJOR SOIL GROUPS	TERRAIN
WET ZONE	Up Country	WU_1	125	Red-Yellow podzolic soils and mountain Regosols	Mountain-ous, steeply dissected, hilly and rolling
WET ZONE	Up Country	WU_2	75	Red-Yellow Podzolic soils and mountain Regosols	Mountainous steeply dissected hilly and rolling
WET ZONE	Up Country	WU_3	55	Red-Yellow Podzolic Soil with dark B horizon; and Red-Yellow Podzolic soils with promin-ent A_1 horizon	Rolling
WET ZONE	Mid Country	WM_1	125	Red-Yellow Podzolic soils; and Red-Yellow Podzolic soils with semi-prominent A_1 horizon	steeply dissected hilly and rolling
WET ZONE	Mid Country	WM_2	55	Reddish Brown Lato-solic soils, Imma-ture brown loams; and Red-Yellow Podzolic soils	Steeply dissected, hilly and rolling
WET ZONE	Mid Country	WM_3	50	Reddish Brown Lato-solic soils, Imma-ture brown loams and Red-Yellow Podzolic soils.	Steeply dissected hilly, rolling and undul-ating.
WET ZONE	Low Country	WL_1	100	Red-Yellow Podzolic soils; and Red Yellow Podzolic soils with semi-prominent A_1 horizon.	Rolling and undulating
WET ZONE	Low Country	WL_2	75	Red-Yellow Podzolic soils, Red-Yellow Podzolic soils with strongly mottled sub soils; and Low Humic Gley soils.	Rolling and undulating
WET ZONE	Low Country	WL_3	60	WL_3-Red Yellow Podzo-lic soils with soft & hard isterite WL_4-Red Yellow Podz-olic soils with soft & hard isterite and Bog & hall Bog soils	WL_3-Rolling & Undula-ting flot
INTERMEDIATE ZONE	Up Country	IU_1	85	Red-Yellow Podzolic soils and Mountain Regosols	Mountain-ous stee-ply diss-ected, hilly and rolling.
INTERMEDIATE ZONE	Up Country	IU_2	55	Red-Yellow Podzolic soils and Mountain Regosols	Mountain-ous, stee-ply disse-cted, hil-ly and rolling.
INTERMEDIATE ZONE	Up Country	IU_3	45	Red-Yellow Podzolic soils	Steeply dissected hilly and rolling
INTERMEDIATE ZONE	Mid Country	IM_1	55	Reddish Brown Earths and immature Brown Loams	Rolling, hilly and steep
INTERMEDIATE ZONE	Mid Country	IM_2	45	Reddish Brown Earths and immature Brown Loams.	Rolling hilly and steep
INTERMEDIATE ZONE	Mid Country	IM_3	35	Immature Brown loams, Reddish Brown Lato-solic soils; and Reddish Brown Earths.	steeply dissected hilly and rolling
INTERMEDIATE ZONE	Low Country	IL_1	40	Red-Yellow Podzolic soils with strongly mottled sub soil, Low Humic Gley soils, Red-Yellow Podzolic soils with soft and hard laterite; and Regosols on old red and yellow sands	Rolling, undulating and flat
INTERMEDIATE ZONE	Low Country	IL_2	45	Reddish Brown Earths, Immature Brown Loams and Low Humic Gley soils	Rolling, hilly and undulating
INTERMEDIATE ZONE	Low Country	IL_3	35	Reddish Brown Earths, Non Calcic Brown soils and Low Humic Gley soils	Undulating

Contd.....

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Zone	AGRO-ECOLOGICAL REGION & SYMBOL		75% EXPECTANCY VALUE ANNUAL RAINFALL (inches)	MAJOR SOIL GROUPS	TERRAIN
DRY ZONE	Low Country	DL_1	30	Reddish Brown Earths and Low Humic Gley soils	Undulating
		DL_2	35	Non Calcic Brown soils, Reddish Brown Earths, soils on old alluminium. Solodized Solonetz, Low Humic Gley soils and Regosols	Undulating and flat
		$DL_{3\&4}$	23	DL_3-Red-Yellow Latosols and Regosols DL_4- Solodized Solonetz, Solonchaks and Grumusols	DL_3- Flat to alightly undulating DL_4- Flat
		DL_5	20	Reddish Brown Earths with high amount of gravel in sub soil, Low Humic Glay soils and Solodized Solonetz	Undulating and flat

The agro-ecological zones of the island offer a broad base for classification of our soils. Fifteen map units have been identified in the dry and semi-dry intermediate zones of the island, while another 12 have been identified in the wet and semi-wet intermediate zones. Factual and interpred information on these soils are used in land use planning, and for maximizing their agricultural productivity. The extent, composition, present and potential land use and the optimum management for each of these soil groups will ensure maximum utilization of the land and its consideration for sustained productivity and use for posterity.

Because of the extensive plans envisaged for future agricultural development and the greater demand made by the increasing population it is necessary that soil, our most valuable natural resource, be conserved. Although conservation and development often seem imcompatible, conservation is a prerequisite.

Erosion of the soil is a natural and continuous process. In undisturbed ecosystems, soil regeneration and erosion occur at approximately the same rate, mostly because the soil is sheltered by a protective vegetative cover. Where the soil and vegetation are not in

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balance as for example in places where human influence and activities are considerable, there could be accelerated erosion with disastorous consequences. In the tropics soil degradation is rampant, and with soil also goes any added fertilizers. The many earthslips reported in our country from the time to time indicate the gravity of the problem. Inspite of the Soil Conservation Act No. 25 of 1951, land is still being abused for quick returns. In addition, floods take their toll in certain areas, while soil problems like salinity, alkalinity or iron toxicity also cause problems.

In order to halt the rapid deterioration or losses of good crop lands, measures should be taken to conserve soil. Systems of production adopted to ecological conditions in which modern technology and techniques are intergrated with traditional systems of resource management should be encouraged in addition to the conventional methods of soil conservation.

With the strides towards industrialization and rapid urbanization soils are likely to get polluted like the rest of the environment. Control of the discharge of industrial effluents and toxic substances will help conserve the soil and water in its natural form for use by man and animals.

3. SOILS OF THE WET AND SEMI-WET INTERMEDIATE ZONES

The low country wet zone generally receives relatively high amounts of rain. The rains alternate with relatively dry periods, thus giving a bimodal pattern of rainfall. The temperatures in the region also alternates with periods of dry weather, and this favours intense chemical weathering of rocks and consequently results in the formation of soils tending towards the typical laterites, in which the silica/sesquioxide ratio is less than 2. Soils with silica/sesquioxide ratios greater than 2 are likely to be formed in areas of low rainfall, impeded drainage, or with parent material not conducive for formation of lateritic soils.

Moorman and Panabokke in 1961, proposed a classification of the island's soils on the basis of their morphological characteristics. The soil units were distinguished by the diagnostic features like their colour, texture, structure and consistance, of the genetic soil horizons.

According to de Alwis and Panabokke (1972) ten map units have been identified in these two regions. They are:-

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1. Red-Yellow Podzolic Soils & Mountain Regosols: Mountainous terrain
2. Red-Yellow Podzolic Soils: Steeply dissected, hilly and rolling terrain.
3. Red-Yellow Podzolic Soils with strongly mottled subsoil & Low Humic Gley Soils; rolling and undulating terrain
4. Red-Yellow Podzolic Soils with soft or hard laterite: rolling and undulating terrain
5. Red-Yellow Podzolic Soils with dark B horison & Red Yellow Podzolic Soils with prominent A_1 horizon: rolling terrain
6. Red-Yellow Podzolic Soils with semi-prominent A_1 horizon: hilly and rolling terrain
7. Reddish Brown Latosolic Soils: steeply dissected, hilly and rolling terrain
8. Immature Brown Loams: steeply dissected, hilly and rolling terrain
9. Bog and Half-bog Soils: flat terrain
10. Latosols and Regosols on old red and yellow sands: flat terrain

In addition two more map units which are also common to the dry and semi-dry intermediate zone also occur in these zones viz:

1. Alluvial Soils of variable drainage and texture: flat terrain
2. Regosols on Recent beach sands: flat terrain

(a) Red-Yellow Podzolic Soils - Ultisols

This is the most extensive soil in the wet zone of the island (Moorman and Panabokke, 1961). Typically, soils of this group occur in the hilly and steepy sloping landscape of the wet zones, and on the sharply rolling terrain of the Badulla-Bandarawela region of the intermediate zone.

The term red-yellow podzolic soils is not a very satisfactory term to describe these soils which have no relationship to the classical podzolic soils described in Europe.

These soils have been described earlier as laterites, lateritic soils or lateritic red loams and earths, reddish to yellow red lateritic yellow loams. In Sri Lanka, the "patna" and "kekilla soils" described by Joachim are also included within this group (Joachim 1935, 1936, 1937; Joachim and Pandithasekera, 1937; Panabokke, 1967).

These soils are generally deep and well drained. An undisturbed soil under the natural vegetation of the wet zone forest may have a A horizon ranging from 25 to 35 cm in thickness. However, in most cultivated soils this may be much less because soil could be

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easily lost by erosion. The soil in the A horizon is dark brown to dark grey brown in colour, and in the un-eroded condition varies from moderately coarse to a moderately fine texture. Under forest conditions the structure varies from weak crumb to moderate crumb, but this becomes less distinct in cultivated soils. The consistence of the soil is friable either in the dry or moist condition, but becomes somewhat sticky when in the wet state.

The B horizon varies in thickness depending on management history etc. In areas not subject to heavy erosion it may be more than 100 cm thick, but could be even more than two or three times this thickness is certain locations. Usually the soil in this horizon is red to yellowish red or yellow in colour. The texture of this horizon is characteristically heavier than that of the surface horizon i.e. more clayey, thus tending to be moderately fine to fine textured. Its structure is usually strong to moderately subangular blocky, while its consistence is friable in both dry or moist conditions. When wet it is slightly sticky.

The C horizon is a mixture of highly decomposed parent rock with many mottles, which may extend from the lower parts of the B horizon.

The red-yellow podzolic soils occuring in the wet zone and semi-wet intermediate zone of the island have been described in six map units (de Alwis and Panabokke, 1972) as follows:

(i) Red-yellow podzolic soils (60-75%) and mountain regosols (20-30%)

These occur on large, high hills and on their slopes in the Kandy, Matale, Nuwara Eliya, Kegalle, Ratnapura, Badulla and Moneragala districts. They are all well drained and mostly are under forest, tea or cardomom at present. The steep slopes are uneconomic for any agricultural ventures, and erosion slopes control would be a major management problem, while slumping and sliding of these soils often occur during heavy rains.

(ii) Red-yellow podzolic soils

There are approximately 820 hectares of red-yellow podzoic soils on steeply dissected hills and rolling terrain distributed in the Matara, Galle, Kalutara, Colombo, Ratnapura, Kegalle, Matale, Kandy, Nuwara-Eliya, Badulla and Kurunegala districts of the island.

Inclusions, ranging up to 30%, are rock knob plains, steep rockland and lithosols and Low Humic Gley Soils and Histosols.

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The characteristics of these soils are similar to those described earlier, except that the slopes are in general less steep, which makes the soils relatively deeper than those of the former map unit. The red and the yellow members exist intimately mixed in the landscape. Much of the land with this soil is being used. The present land use in the low and mid-country, are tea, rubber, coconut, coffee, cocoa, fruit trees, tobacco and vegetables but there is a great potential for minor export crops, sericulture, horticultural crops, pastures and economic forestry.

Management problems of these soils depend on the crops the land carries. For example, with tea, erosion and nematode infestations would be major problems. These soils generally respond to N and P fertilizers.

(iii) Red-yellow podzolic soils with strongly mottled sub-soil and low humic gley soils

These soils are situated on rolling and undulating terrain in parts of the Kurunegala and Kegalle districts and are estimated to cover an area of approximately 143,000 hectares. In these areas, the low-humic gley soils account for anywhere between 20 to 30 per cent of the extent, while the inclusions of

alluvial soils and lithosols may be between 0 to 10 per cent.

The drainage characteristics of these soils vary from the well to imperfectly drained, and their colour varies from reddish brown to yellowish brown in colour in accordance with drainage. They are somewhat fine textured, and prominent mottles occur in the sub-surface horizons. They are most usually situated in the higher topographical positions of the landscape. The Low Humic Gley Soils of the valley bottoms are not different from those described in the first map unit except that these tend to be slightly more acid in nature.

Coconut, rubber, home gardens, forest are grown and shifting is practiced on the well drained soils, which rice is grown on the pooly drained Low Humic Gley Soils. On the former, coconut, pastures and even irrigated rice are possible. The poorly drained low-lying soils may sometimes require artificial drainage. Fertilizer responses to N and K are common, while Ca and Mg may also be needed for some crops in some locations.

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iv. Red-yellow podzolic soils with soft or hard laterite

Approximately 236,000 hectares of this map unit occur on rolling and undulating terrain of the Kurunegala, Colombo, Kalutara, Galle and Matara districts, and accounts for approximately 70-90 per cent of the area. The main inclusions include the Low-Humic Gley Soils, Humic Gley Soils, Bog and Half Soils and Alluvial Soils.

These Red-yellow podzolic soils are much alike those described above in category III. Their sub-soils however, have more well-formed mottles and soft laterite or cabook which can be cut into bricks which hardens on exposure to air. In the natural state it gives rise either to a hard massive rock-like material or to a ferruginous gravel. These lateritic masses are well formed in regions close to the western sea coast, around Kalutara, Beruwela and Galle. As for land use, these soils, carry coconut and rubber in locations where depth of soil is not a limiting factor, and pine apple, home garden crops, vegetables and yams occupy an appreciable extend of these soils. Quarrying of laterite for bricks is also a common feature in these areas.

Soil depth is a common limitation for deep rooted plants on this soil. Lack of

infiltration in some areas, due to the presence of a hard pan is another common problem, which could be easily eliminated by breaking through or ripping to promote infiltration. On steep lands, soil erosion is a serious problem, and in many areas artificial fertilizers would be essential.

(v). Red-yellow podzolic soils with prominent A_1 horizon

These soils have a characteristic, very dark A_1 horizon rich in organic matter. This layer may be as much as 30 cm. in thickness and supports the typical wet patana vegetation or montane forests (in the Nuwara Eliya district) and the kekilla, fernland vegetation in other areas as described by Joachim and Pandithasekera (1937).

As estimated 12,300 hectares of this sub-group with dark B horizon lies intermixed with Red-yellow podzolic soils, mainly in the Horton Plains, and Bopatalawa regions of the Nuwara Eliya districts, and in the Rakwana and Deniyaya regions. Bog and Half-Bog soils and Meadow podzolic soils are the common inclusions which range between 5 to 20 per cent. They occur in the water logged valley bottoms.

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These soils which are situated on the upper aspects of the landscape are well-drained and moderately fine textured and strongly acid. The subsoils are dark coloured.

Soils with the prominent A_1 horizon occur on the lower portions of the landscape. They are well-drained and strongly acid in reaction.

Tea, vegetables, potato, orchard crops and pasture are the main agricultural crops grown on these soils.

Soil and water conservation are important management aspects on these soils. Due to their acidity, liming may be necessary periodically while N, P and K fertilization would be needed more often. Ca, Mg and probably S could also limit plant growth and development on these soils.

Application of cattle manure has been found useful in supplementing the effects of fertilizers with crops like potato.

(vi). Red-yellow podzolic soils with a semi-prominent A_1 horizon

There are an estimated 24,600 hectares of these soils on hilly and rolling terrain at

elevations between 310 to 1,240 m of the Ratnapura, Kalutara, Galle and Matara districts. In these about 10 - 30 per cent inclusions are steep rockland, and lithosols, alluviaal soils and Bog and Half Bog soils.

The characteristics of these soils are very similar to those described earlier except that organic matter is not so markedly prominent in the A_1 horizon.

Present land use on these soils is confined mainly to tea, with cardamon at the higher elevations, and rubber and coconut at lower elevations.

Because soil erosion and earthslips can be severe in these areas soil conservation is a major management practice on these soils. Due to their acidic nature, liming may be a beneficial factor on these soils, while fertilizers to supplement N, P and K would be needed. Mg and Ca also may be required in certain locations.

(b). Reddish Brown Latosolic Soils

There are approximately 63 thousand hectares of this soil distributed mainly in the Kandy, Kurunegala, Matale, Kegalle and Nuwara Eliya districts. The chief inclusions are the

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Immature Brown Loams, Alluvial soils, and Low Humic Gley soils which account for approximately 10 to 30 per cent.

These soils occur in all positions of the rolling, hilly and steeply dissected landscapes except in the valley bottoms. As the name implies they are reddish brown in colour, are well to moderately well drained, moderately fine textured, and somewhat acid in reaction.

At present these soils support mainly tea, rubber (if elevation permits), coconut, cocoa, coffee, kitul, arecanut, pepper, kapok, banana and other fruit crops, vegetables, and mixed home gardens. However, a wide variety of minor export crops like cloves, cinnamon, nutmeg and vanilla, together with mulberry or pastures, can be successfully grown on these soils. In addition to the above, cocoa and coffee would also be best suited.

The Reddish Brown Latosolic soils possess good physical and chemical properties. Moderately high responses to N, P and K fertilizer could be obtained on this soil. They are also fairly well supplied with Ca and Mg. Erosion could be a problem on the steep slopes, and therefore conservation measures are important.

(c). The Immature Brown Loams - Dystropepts

These soils occur in close association with the red yellow podzolic soil. They are very young soils, developed on mica schists which occur in the Kegalle and Kurunegala districts. Joachim (1936) first used this term which was retained until 1967, and the equivalent term in the 7th Approximation, Dystropepts is used now (de Alwis and Panabokke, 1972).

The estimated extent of land covered by this soil group is approximately 54,530 hectares, in which between 10 to 40 per cent may include the Reddish Brown Latosolic soils, Low Humic Gley soils and Alluvial soils. They occur on rolling, hilly and dissected land forms, but not in the valley bottoms.

Morphologically, the Immature Brown Loams are moderately deep and well drained. As they are relatively young, immature soils, many undecomposed primary minerals like fine micas occur throughout the whole depth of the profile.

The A horizon is between 15 to 30 cm deep and is dark brown to dark gray brown coloured and is somewhat coarse textured with ample quantities of fine micas. It is moderately crumb structured but may be weak subangular

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blocky. Its consistence is friable when dry or moist, and is not sticky when wet.

The B horizon is uaually 55 to 85 cm thick, is lighter coloured usually yellowish brown, compared with the A horizon. It is however darker than that of the C horizon below it.

The texture of this horizon ranges from moderately fine to moderately coarse textured and, like the A horizon, contains unweathered minerals. Its structure is mostly indistinct, but could sometimes be weak subangular blocky, while its consistence is friable either in the dry or wet condition but not sticky when wet.

The C horizon exhibits much of the original structure of the micaceous rock and contains decomposing rock fragments. Portions or sections of the B horizon often intrude into the C horizon in irregular patterns.

As for their potential land use, they carry the same crops as do the reddish brown latosolic soils often found associated with them. Very often, however, only shallow rooted crops like vegetables, yams or pastures are grown on these soils due to the shallowness of these soils.

Erosion is a major hazard on steep slopes.

Some crops may have to be provided with supplemental irrigation because these sols tend to dry up rapidly. While they are amply supplied with K, N and P could be limiting. They are well supplied with Ca and Mg.

(d) The Histosols

The histosols, which were referred to as the Bog and Half Soils in the earlier description (Dimantha, 1977) occupy approximately 51,000 hectares in the wet zone. Their greatest distribution is in the districts of Colombo, Kalutara, Galle and Matara, although these also occur in certain parts of the Ratnapura district. An appreciable propotion of alluvial soils of the wet zone have histosols as inclusions in the poorly drained locations, i.e. slack water deposits and back swamps. These may also be filled up lagoons, tidal marshes narrow valleys or tongues, some distance inland where drainage is restricted or impeded. Generally the histosols would occur at elevations approximately below 1.6 m m.s.l. Good examples are the peaty soils of Muturajawela, and those on the banks of the Nilwala Ganga at Matara. Salt water intrusion during high tide in areas close to estuaries of rivers is a common problem on these soils; and therefore salt water exclusion bunds and

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regulators have been constructed for prevention of salinity in soils. The mean diffeerence between high water and low water level in our coastline is approximately 45 cm.

The natural vegetation on histosols, in many places, consists of grasses and sedges with extensive, deep root systems which help in the accumulation of organic matter, especially due to the anaerobic conditions that exist in these water-logged situations. Thus decomposition of organic matter is slow compared with accumulation. Further, the soils tend to be carried away by flood waters due to their low bulk density.

The major soil forming processes these soils are threefold (Dimantha, 1977). They are (i) the accumulation of parent material i.e. organic matter, and mineral alluvium and colluvium, (ii) the formation of gley horizons and soils due to reduction conditions that prevail, and (iii) leaching of bases and the nutrients resulting in acid soils.

Traditionally, rice is grown in most Histosols if free of physiological maladies. Grasses and sedges for mats, baskets, sun-hats etc. are also grown in some areas. Other useful plants found on these are:- Bacofia monnieria

S. Lunuwila) for Ayurvedic medicine, Sonneratic caseollarig (S. Kirala) for its edible fruits and roots used as substitute for bottle cork, and Nipa fructans (S. Gin pol).

Management problems will include improving soil drainage reducing flood hazards, timely planting to avoid floods and rains during critical periods of growth and at harvest (Thenabadu, 1977).

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4. SOILS OF THE DRY ZONE AND SEMI-DRY INTERMEDIATE ZONES

There appears to be relationship between soils and agricultural settlements in our ancient civilizations that flourished in the dry zone regions. For example, those that flourished in the Raja-rata and Ruhuna-rata were situated on some of the best soils of this region i.e. the best of the Reddish Brown Earths - or Alfisols. By tropical standards these soils possess very good chemical fertility and their "associated drinage members which occur in the lower topographical aspects of the undulating landscape are indeed rice soils 'par excellence' in respect of their inherent potential for sustained yields" --- (Panabokke, 1967).

Until recently, and even today to some extent, Chena or shifting cultivation is practised on the upland soils due most probably to their non-friable nature, which was not conducive to settled arable farming. A non-fariable soil is hard when dry making it difficult to till manually or with bullock drawn ploughs. The most important soils of the dry zone and semi-dry intermediate zones are the Reddish Brown Earths, Non-Calcic Brown Soils, the Red-Yellow Latosols, and the Gummusols.

The largest potential for expansion of agriculture lies in the dry zone of the island; and much studies have been devoted to the soils, land classification and rainfall expection in relation to cropping patterns of this region. The Land Utilization Committee (1967) reported six Agricultural Land Classes as presented in Table II.

It should be noted that 55 percent of the land surface of the dry zone consists of agriculturally good land, while another 15 percent can be economically exploited.

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Table 11 Agricultural Land Classes of the Dry Zone

Agricultural Land Class	General Characteristics of Land Class	Per cent
Class I	Land which is quite suited for agricultural development because both soil and terrain have no significant limitations	49.0
Class II	Land which is moderately suited for agricultural development because of very slight limitations in either soil or terrain	6.1
Class III	Land which is moderately marginal for agricultural development because of few limitations in either soil or terrain, which could however be economically remedied	15.0
Class IV	Land which is marginal for agricultural cropping because of at least one serious limitation in either soil or terrain; this land is however quite suited for either grazing or forestry	10.0
Class V	Land which is unsuitable for agricultural development because of more than one serious limitation in either soil or terrian; this land is suitable for forestry as well as nature reserves	11.7
Class VI	Land in which the obstacles to agricultural development is so great that it should remain in forest or be re-afforested	8.2
	Total	100.0

(a) The Reddish Brown Earths - Alfisols

These soils are so named because of their characteristic reddish brown colour. They have been described earlier by Joachim as (i) the non-lateritic and reddish brown loams and, (ii) the chocolate brown loams which are developed on dolomitic limestone, in the Matale and Polonnaruwa districts in close association with the former soil.

This is the most extensive soil group in Sri Lanka and the most important in comparison to all other soils in the country. They have been derived from a variety of crystalline Archaean rocks.

The early Aryan settlers in the island, it is believed, found the plains of Rajarata affording more favourable conditions for rice cultivation compared to the region of dense vegetation and forests of the south-western regions which are endowed with abundant rainfall. Further in the Rajarata they would have found that the terrain was less interferred by rock outcrops and hills than in the more southernly region of Maya-rata (Panabokke, 1969).

As already mentioned, these reddish brown

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earths occupy the largest extent of land in the dry zone of Sri Lanka and cheifly in the districts of Anuradhapura, Polonnaruwa, Vavuniya, Hambantota, Moneragala and Trincomalee.

These soils occur on undulating as well as rolling landscape and are confined mostly to the well drained higher topographical aspects of the landscape. In the middle aspects of the topography are the yellowish brown earths, while in the lower aspects occur the low-humic gley soils.

The best of the reddish brown earth soil regions are in the Rajarata or the Nuwara-Kalaviya geographic area of the Anuradhapura district and in the Ruhuna-rata geographic area of the hambantota district.

The parent material of these soils is derived from Archacean rocks which are fairly acid to highly basic and contain appreciable amounts of ferro-magnesian minerals.

The average annual rainfall in the majority of the areas covered by this soil is approximately 215 cm. The natural vegetation is dry, evergreen forest. The evergreen species predominate admixed with deciduous species. In most parts secondary forests predominate.

These soils are moderately deep and well drained. The A horizon is usually 12.5 - 25 cm deep and moderately fine textured. A quartz layer or "stone line" of variable thickness occurs at some depth in the B horizon. This prominent quartz-gravel or ironstone-gravel layer is a characteristic feature of these soils. The texture of the B horizon is heavier than that of the A and is usually moderately fine textured with a variable proporton of quartz and iron stone gravel (Panabokke, 1958, 1959).

The structure of the B horizon is strong, sub-angular blocky. On drying the soil gets hard and when wet it gets very sticky. It is slightly friable when moist.

The C horizon is more or less decomposed parent material.

As for the reaction (pH) of the soils, they are mostly neutral, but tend towards slight acidity as rainfall increases in areas. In the more drier areas the pH may be slightly to moderately alkaline.

Nitrogen and the related organic matter contents of these soils are low, and so is that of phosphorus. Potassium on the other hand tends to be medium to high.

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The cation exchange capacity (CEC) of these soils is higher than in most other soils of Sri Lanka (except the Grumusols of Vertisols). The soils are well supplied with exchangeable calcium and magnesium.

(b) Non-Calcic Brown Soils

This group which occurs mostly in the inland regions of the Batticaloa and Amparai districts, within the same areas as the Reddish Brown Earths, develops only from parent rocks deficient in ferro-magnesian minerals. Thus they are especially widespread in the Eastern Province on highly acid gneisses, rich in quartz and poor in biotite and hornblende.

In parts of Gal Oya Valley, Bintenna and around Maho these soils occur in a complex pattern together with the reddish brown earths. They are much inferior to the latter in fertility, and occur usually in the well drained higher aspects of the undulating to rolling relief of the dry zone. In the lower aspects of the topography occur the low-humic gley soils in most locations. Appreciable amounts of the land surface in these areas is occupied by erosional remnants and low, rock out crops.

These soils are shallow to moderately deep and

moderately well drained. The quartz gravel layer is either weakly exposed or might be almost absent. The horizon is 15-18 cm and gray brown to yellow brown in colour. The texture is moderately coarse and the structure is very weak crumb to weak subangular blocky.

The C horizon consists of decomposing acid gneisses which are very light coloured due to the low content of ex ferro-magnesian minerals.

(c) Vertisols (Grummusols)

In the past, these soils were referred to as the black cotton soils (or black tropical soils) due to their resemblence to the well-known soils of India.

The vertisols are found to occur in approximately 400 hectares of flat terrain or gentle depressions, and almost all are confined to the southern part of Jaffna and northern part of Mannar administrative districts. They are best seen around Tunakai (Kilinochchi) and Murunkan (Mannar). Generally there are no other soil inclusions.

Morphologically, these are typically A-C profile soils due to the absence of a natural B horizon. The A horizon is black or very dark

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grey brown coloured and contains heavy, montmorillonitic clay.

The consistency of the soil is sticky when wet and extremely hard when dry. On drying the soil cracks up, leaving wide spaces in between due to alternate swelling and shrinking. The width of a crack may be as much as 12 to 13 cm.

The present land use of these soils is limited to rice, but vegetables, chillies and legumes could be grown on ridges during the Maha season. During the Yala season supplementary irrigation may be necessary.

The physical properties of this soil are not very suitable for good agriculture, although their chemical properties are desirable. The soils are difficult to work with because they become extermely sticky when wet and extremely hard when dry. An additional problems is water logging, in areas of lowlying topography. The use of machinery for tillage etc. is not feasible. These soils respond well to N and P fertilizers.

(d) Oxisols (The Red-yellow Latosols)

These are the most ancient soils found in Sri Lanka (Panabokke, 1967) and are estimated to cover approximately 0.8 thousand hectares.

Their distribution extends from north of Puttalam, in the north-western dry zone, over the northern portion of the island, to Mullaitivu on the eastern coast. Isolated patches of the red-yellow latosols occur also in the south-eastern coastal plains, while its calcic sub-group occurs exclusively in the Jaffna peninsula.

This region, had been sparsely settled in ancient times probably due to the lack of surface water reservoirs. Only recently are these areas exploited after the harnessing of underground water in Vanathavillu.

The soils are very friable but extremely poor in chemical fertility. They are also characterrized by their very poor water holding capacity.

The lack of surface storage tanks in this area is due to the very porous nature of these soils. The rapid infiltration of water to great depths where it is stored in the substratum.

Factors that permitted a settled system of arable farming in the Jaffna peninsula are, the friable nature of the soils and the assured water supply at convenient depths which could

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be exploited even with traditional water lifting devices.

(e) Alluvial Soils

Approximately 450 thousand hectares of alluvial soils occur on flat, flood plains of major rivers, and in valley depressions and back swamps. They have been transported and deposited by water during geologically recent times. Most of these in the dry regions may have up to 10 percent solodized sononetzs. They show no profile development, except perhaps some accumulation of organic matter on the surface horizon, and some degree of stratification.

As to be expected, much variation in texture (which ranges from sand to clay), depth and colour is observed in these alluvial soils. Their colours are variable, ranging from reddish or brownish grey to black depending on the degree of submergance and reduction and the contents of organic matter. Even their drainage characteristics would be variable and range between well to very poorly drained.

Natural grasslands (villus) predominate on these soils. Sugar cane and rainfed or irrigated rice are the main agricultural uses of these lands. Some of the

more clayey alluvial soils are used for manufacture of bricks and tiles. Others are good sources of river sand used in building construction etc. Gemming is another common venture on these soils.

Flooding is a common hazard on these soils. However, its advantage lies in the fact that this phenomenon supplies plant nutrients for the next cropping season. Moderate responses to N, P and K fertilizers can be expected on most of these soils.

Alluvial soils of variable drainage and texture occur on flat terrain in almost all districts of the Wet and Intermediate zones of Sri Lanka. They are invariably associated with Half Bog and Bog Soils (Histosols) to the extent of about 5 to 15%.

Soil fertility and physiological problems may be common on these soils, especially if their drainage is poor. Responses to P and K fertilizers are generally good with rice and other crops.

They are good sources of clay for brick and tiles, if clayey, or afford sand for construction. Gemming is another common form

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of land use on the soils. Rice is grown where water is assured or where the land is not exceptionally water-logged.

(f) Regosols

It is estimated that 138 thousand hectares of regosols exist on recent beach and dune sands in the dry and semi-dry intermediate zones of the island.

These are very young soils with little profile development situated on flat terrain along the coastlines of the Batticaloa. Trincomalee, Puttalam, Mannar, Anuradhapura and the Jaffna districts. Solonchaks may be found as inclusions to the extent of approximately 10 percent.

Regosols are very deep soils and white coloured due to the predominance of sand. They extend from the seabed across the sand dunes to the elevated beach plains, and are well to excessively drained sand.

They support coconut, palmyrah and cashew on shallow regosols, among the economically important crops. The other areas are under scrub forest and parkland. Potato is a potential crop during the cool months of the

Maha Season but supplemental irrigation may be necessary. The black pigment ilmenite the titanate of ferrous iron ($FeO-TiO_2$) is exploited from these regosols in certain areas.

Ensuring adequate moisture for plant growth and establishment is a problem of major concern on these soils. Due to severe drainage losses, frequent split applications of fertilizers are recommended in preference to heavy single applications. As to be expected, these soils are deficient in almost all essential nutrients.

(g) Miscellaneous Land Units

Three map units of little or no agricultural value or potential, occur in the lowland dry and intermediate zones. The first of this is :

1. Rock Knob Plains found in all districts where exposed rocks cover a very high proportion ranging from 10 to 80% of the land area while lithosols and similar soils occupy the other areas.

These rock knob plains are best utilized to exploit their rock for construction purposes. They should otherwise be left as nature, wild life or forest reservations.

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2. Eroded lands on undulating plains where the underlying basal, iron stone gravel and nodules are exposed due to loss of soil from red yellow latosols. These occur mostly in the Vavuniya, Jaffna, Mannar, Anuradhapura and Puttalam districts.

These lands could best be left as wildlife reserves or the gravel could be exploited.

3. Erosional remnants or inselbergs are found in almost all districts of the dry and intermediate zones and comprise isolated hills and ridges of unweathered resistant bedrock which stand prominently over and above the lowland plains.

Most of them are historical or religious significance today, and afford possibilities for tourism and recreation. In the Kandy, Ratnapura, Nuwara Eliya, Badulla and Moneragala districts there are steep rockland and lithosols which are largely steep scarps and cliffs of bare rock or lithosols with thin layers of soil.

They are of little use other than for recreation or sources of rock for construction activities.

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PART II
SOIL CONSERVATION

1. INTRODUCTION

It is no exaggeration that, man, despite his artistic pretensions, sophistications and many achievements in science and technology, owes the fact of his existence to a thin layer of top soil, and to water and air. This is applicable to almost all forms of life on earth. It is also paradoxical that water and wind acting singly or together do untold damage to soil, although water and the active constituents of air play very important roles in the formation of soil from bare rock.

Bringing new land under cultivation still constitutes an easy means of increasing gross agricultural production, especially in sparsely populated areas. It has been estimated that a minimal 20 million ha of additional land will have to be cleared for cultivation to meet the food demands of the expected world population by the year 2000 A.D. The ambitious agricultural and settlement projects in Sri Lanka, like the Mahaweli, Sevanagala and Samanalawewa will also involve the opening up of large areas of new land. However, increasing production per unit land area and

sustaining it over a long period of time is a decisively better alternative. In a country like Sri Lanka where land is limited, and good agricultural land is scarce this is especially, important particularly in densely populated areas, and in all areas in general. In fact the objectives of agronomic research is to develop land management systems to increase intensity and efficiency of production per unit area per unit time. This increase in intensity of production should best be achieved with the minimal damage to the natural resource base and to the environment. It should be remembered that this natural resource base is a shrinking commodity due to rapid, and often irreversible, degradation of physical, chemical and biological properties of the soil.

In the centuries past, ancient civilizations survived probably as long as the productive capacities of the soils were restored due to natural requistion or regeneration, by <u>chena</u> or shifting cultivation and related bushfallow systems.

On the other hand, continuous cultivation results in rapid decline in soil productivity due to reduction in soil organic matter which is related to the effective cation exchange capacity and the water and nutrient holding

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capacities of soils. Soil compaction which also results from continuous cultivation results from continuous cultivation results in reduction of the soils macroporocity and transmission pores, high soil temperatures and frequent moisture deficits during dry periods and insufficient oxygen in the root zone.

Continuous cultivation of soils have brought about profound changes in ecological environments with deliterious effects on crop growth. In his quest for producing more food man has set in motion degradative processes which are accentuated by accelerated soil erosion.

The soil resources of the world have been estimated to be shrinking at an alarming rate of 5 to 7 million ha due to degradation of the soil and because of agricultural uses. An important factor that influences soil degradation is soil erosion.

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2. SOIL EROSION BY WATER

Water is an powerful eroding force, especially in tropical countries like Sri Lanka. In most instances, it causes erosion by detaching soil particles from the surface soil mass and transporting these particles downhill. Erosion by water can take place under natural rainfall conditions, or under irrigated conditions.

Three main types of rainfall have been recognized in Sri Lanka. They are:-

(i) Monsoonal or Orographic
(ii) Conventional
and (iii) Depressional

Forest cover is said to have no effect on depressional or cyclonic rain. Monsoon rain, may on the other hand be affected somewhat by the height of the vegetation or forests, and the frictional influence of the irregular surface of the forest cancopy on the wind. According to Koelmeyer (1960) it is more likely, that in Sri Lanka the influence of forests on rainfall is mainly confined to microclimatic conditions by assisting in local rainfall.

The erosive action of water is greatest when

the protective vegetative cover is removed, and the bare land surface is exposed to the direct, lashing action of rainstorms.

Movement of soil by rain water is a complex process and is influenced by many factors. The most important of these are:- (1) the amount, (2) the intensity, (3) duration of rainfall, (4) amount and velocity of surface flow. (5) nature of the soil, (6) the ground cover, and (7) slope of the land surface. The erosive power of water is determined by the interaction or balance of several factors, some of which favour soil movement and others that oppose it. The "Universal Soil Loss Equation" takes all these factors into account.

Before any soil material is transported it has to be dislodged or detached from its position on the aggregate, or surface of the land. Subsequently it is splashed, rolled, slid or carried in suspention along the surface, by water running downhill. These processes are due mostly to raindrop splash and to flowing water.

Both inherent soil properties and changes brought about by land use or misuse, human interference especially by cultivation and other disturbances to the soil, play a part in

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water-erosion. Thus, there are differences in the degree of erodibility of soils in different areas.

In tropical areas water erosion is initiated when raindrops strike the soil surface and disintegrate the clods and soil aggregates. (In temperate areas melting snow can cause erosion). Three steps are involved in the process. They are: (1) removal of the soil material from soil mass that turn loose from moorings, the particles, (2) transportation of detached soil material, and, (3) deposition of the soil material.

Thus during rainstorms the two major agents of erosion that become active on land are falling raindrops and flowing water. The kinetic energy of these raindrops can detach soil particles and the energy of flowing water which is usually applied paralled to the soil surface is capable of transporting this detached soil material. Therefore, falling raindrops and flowing water are by themselves both powerful and destructive erosive agents. When there is shallow surface flow in the prechannel stages of erosion, they work together.

1. Splash-Erosion

Falling raindrops have the capacity to erode

soil. The erosive capacity of the rain drops depend on the energy per unit area of the drops. The kinetic energy of raindrops has been estimated to be 10^4 ergs, for drops of 2 mm radius; while that in a drop of radius 2.5 mm is estimated to be capable of raising a 46 g body to a distance of one cm.

The kinetic energy of rain drops increases as rainfall intensity increases, the rate of this increase being 1.2 power of the intensity. Except for a very small proportion of this energy which is dissipated in the form of sound and heat, the greater proportion is expended instantly against the soil surface. Raindrop impact makes soil move downwards, sideways and upwards. In other words raindrops spread and splash soil particles.

Falling raindrops also compact soils. Such compacted soils could suddenly lose their capacity to infiltrate water, and when this happens high runoff occurs during heavy rains.

The action of raindrops which cause decreased rates of infiltration depends on the size of rain drops as well as on their velocity. Their effectiveness increases directly as the proportion of large drop increases, and as their velocity increases. This surface flow

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has little or no rotational energy to keep the soil suspended. It is at this stage that falling raindrops could keep the water turbid and thereby increase the ability of flowing surface water to transport the soil particles.

Falling raindrops act like a levelling agent, and smoothens the land surface, while flowing water tends to collect in small rills and then in small channels which cover and collect in streams. Unlike raindrops, flowing water therefore causes rough surfaces by cutting channels or gullies.

2. Puddle-Erosion

Clods and soil crumbs are shattered and soil structure is destroyed during violent storms. This gives rise to a puddled condition in the soil and is caused by the sharp impact of rain drops on the exposed soil. The finely divided constituents of soil are transformed into an impervious layer of surface mud, by the beating and churning action of rain drops which also compact the soil particles.

This compact layer then becomes more denser and more impervious because colloids and other small sized particles carried by the turbid water, filter down from the surface and accumulate in this layer. Thus the porosity of

the surface layer is reduced appreciably, due to infilteration of muddy and murky materials from the surface. Channels to the deep soil get blocked, and aeration and infiltration inevitably get reduced. The crusts seen on a newly ploughed field after a storm, when the soil surface acquires a glazed appearance are due to puddle erosion.

A plant cover, especially low-growing plants, or a mulch protects the ground surface against the impact of falling raindrops and helps soil to maintain its structure. Hence the value of cover crops, in plantation agriculture or horticultural crops; and mulches in fields exposed to sun and rain. In the choice of cover crops preference is given to leguminous crops due to their ability to fix atmospheric nitrogen.

3. Fertility-Erosion

The fertility of a soil resides principally in the top soil, and this is also the portion of soil which is subject to the strong stresses from erosion. Their actions are more on the top soil than on any other part of the soil profile.

Most soil particles dialodged by raindrops are generally less than about 2 mm in diameter.

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Few particles may, however, be larger than this. As splashed soil falls back into the water on the soil surface, many of the finer particles are carried away, while the coarser material would settle down after travelling a short distance downhill. This gives rise to fertility erosion and an excess of coarse material accumulates on the surface. By this process much of the organic matter and fertility-bearing material of the soil may be floated away even if the land appears to be level for all practical purposes. Thus the soil is left relatively infertile.

In addition fertilizer materials, especially insoluble phosphates, or soluble phosphates which have got fixed in soil get washed off in this manner. On the other hand nitrogenous fertilizer will get leached away or washed off because they are invariably water soluble.

Run-off and leaching of fertilizer from agricultural lands have their effect on the natural environment, and leads to eutrophication.

4. Sheet Erosion

Sheet erosion is almost entirely splash erosion because splash erosion tends to remove this

sloping top-soil in this sheets. For example, sheet erosion occurs on all hills and sloping land where the energy of splashing raindrops acts uniformly throughout an area on which rain falls. This favours the movement of soil at the crest of the hill where the least amount of energy is required to transport soil and more energy is therefore available for dislodging the soil particles. At some point downhill, all the energy of the raindrops may be used up in resplashing soil that has been splashed down from above. Therefore, below this point there will be little or no loss of soil due to the splash process only.

Splash erosion moves soil downhill, but does not transport it appreciably away from the base of the slope.

Splash erosion moves soil downhill, but does not transport it appreciably away from the base of the slope.

Sheet erosion or wash strictly does not follow any definite channels. Water tends to concentrate its flow, however, and small drainageways are soon developed. These channels continue to grow with each successive rain, unless the soil is covered and protected

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by vegetation or a mulch. These channels are prone to increase in size and form gullies which are too large to be levelled or smoothened over by normal tillage. The amount of sand and silt that often accumulates at the lower side of a sloping field, after a heavy rain, is an indication of the volume of material which could be removed, and be lost, from a field by sheet wash and cutting.

Human activity and interference with the environment often results in rapid sheet erosion, and this very often results in marked wearing down of precious land.

5. Stream-Erosion

Streams are normally active agents of erosion. They could, however, become still more active and violent due to changes brought about by man. For example, if the natural vegetation in an area is removed, the amount of water which runs off during or immediately after a rain increases in proportion.

In hilly or mountainous areas streams flow at a high gradient in narrow, steep-sided valleys. They are vigorous and they actively erode the bottom of their channels. In less hilly or rugged areas where the land is worn down, streams and rivers flow in flat-bottomed

valleys. They have broad, flood plains. At this stage of maturity streams usually cut the land sideways (sidewards) and they swing or meander from one side of the valley to the other. In this process they broaden the flood plain and erode the banks. The banks cave in and slump due to undercutting by streams, and this gradually erodes away the lands adjoining stream. This danger will be increased if plants or other vegetation along the banks are removed from the banks.

Cracks open parallel to the gully margin while holes of burrowing animals together with decayed plant roots often allow the rain water to enter the soil. This causes large blocks of the gully wall to collapse.

The development of a valley within a valley is an indication of an increased rate of erosion, and most landscapes would be dull without this phenomenon, but this is too expensive an idea , involving very valuable soil, our national wealth.

Nevertheless it would be well to remember that the process of erosion is of great importance in the geological history of the world, for it is one of the main factors that cause immense changes which slowly and steadily alter the

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configuration of the earth's crust. Recent human activities have caused rapid local erosion which has turned large tracts of fertile lands into deserts. This "disease" of desertification is spreading, and threatening an appreciable proportion of the world's land surface, and will affect the livelihoods of millions of people, if immediate steps are not taken to arrest its spread.

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3. WIND EROSION

Wind can be an active factor in soil erosion, and wind erosion is serious in areas where there is inadequate vegetation to cover and protect the soil. The harmful effects of wind erosion in Southern and Western U.S.A. have been amply recorded. This is the usual condition in arid lands and along sandy shores of oceans, lakes and rivers. In these areas sand dunes are common landforms. Storms of blowing sand have been a danger to travellers and inhabitants of desert regions. Although wind erosion is not as serve as water erosion it still could be significant.

A good vetetative cover on the soil is good protection against wind erosion. Like sheet erosion, wind erosion also acts over broad areas. A thick sod or natural forest cover or a cover of vegetative litter is a protection against wind erosion. Selected grasses and trees could be planted to provide permanent anchorage for the loose material.

Sand dunes and their formation could be very destructive to valuable land, buildings, crops or forests. They are reported to have buried forests, houses and even whole villages. Some of these have been uncovered many years later

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when a shift in the wind during a few storms caused the sand to blow in another direction.

Overgrazing and devegetation increase erosion, and the sand and silt produced wash into the rivers and increase their load. Excessive grazing and trampling of vegetation due to overstocking and congregation of livestock, during periods of drought can encourage wind erosion. Once started, erosion becomes rapid as vegetation is buried by shifting sands. In arid and semi arid regions there is seldom enough water to transport this additional burden. Sand flats formed along the rivers and the bare sand can now be easily moved by wind.

Where there is no vegetative cover and little moisture in the soil, the bare soil can be easily transported by wind. Unprotected, fine grained, topsoil blows easily and can be carried greater distances when it is loose and dry. This material fills the air, and clouds the sun for days, giving a weird character to the light. In heavy blows, or "dusters", the fine soil gets into everything. Tightly closed houses may even prove inadequate, from protection of this dust. The blowing sand may, in addition, choke and blind animals and humans. Thus it is important to remember that the place of origin and the place of deposition are both affected by wind erosion.

In severe drought years, the Great Plains of the U.S.A., which are known for their high fertility suffer heavily, when dry soil from ploughed land is blown away and nothing but hard, raw sub-soil is left behind.

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4. PREDICTING RAINFALL-EROSION LOSSES

Many factors influence the erosion of soil by runoff water, and by wind. According to the Universal Soil-Loss Equation (USLE) of Wisohmeier and Smith (1960, 1965) A, the average amounts of soil lost per year per acre in tons, by rainfall, is equal to the product of six factors: R = erosivity, or rainfall, K = soil erodibility, L = length of slope, S = degree of slope, C = crop management, and P = soil management and/or conservation practice. Thus the relationship A = R x K x L x S x C x P

Erosivity (R) is the function of rainfall, while erodibility (K) is the function of detachability and transportability of the soil particles which is a general soil characteristic which cannot be changed much. The factors S,L,C,P can often be held constant for a particular place. Erosivity on the other hand depends on the erodibility, and is inversely proportional to the latter. If erodibility is reduced by other factors, the erosivity can be minimized and soil can be conserved. Measures taken to conserve soil should therefore be aimed at minimizing erosivity. Crop management can reduce erosion to an extent, the factors involved in this being, time of planting, density of planting,

crop rotation systems, ground cover etc. A 100% plant population will have much vegetative cover and will therefore reduce the kinetic energy of falling rain crops and reduce runoff water.

Presumably, characteristics of soil are also important. For example, high permeability results in greater infiltration and therefore this reduces runoff.

Erosivity (R)

Erosivity, or the rainfall and runoff factor, quantifies the effect of raindrop impact and relative information on the amount and rate of runoff most likely to be associated with the rain. In addition to raindrop impact, erosive forces of runoff from thaw, snowmelt or irrigation can also be considerable.

When other factors are considered constant, storm soil losses from cultivated lands are directly proportional to a parameter which is the product of total storm energy and the maximum intensity during 30 minutes. Rainfall energy by itself is not considered a good indicator of erosive potential. The energy of a rainstorm is a function of the amount of rain and of all the storms component intensities.

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Erodibility (K)

Erodibility values are useful for predicting, estimating and controlling erosion hazards. These values are useful in predicting the potential sediment yield in watershed management and for conservation farm planning, where the upper limits of sediment yield or soil loss tolerance values can be established. Ideally, knowledge of these values would enable economical maintenance of soil productivity. Such values are evaluated on the basis of sediment yield per unit rainfall erosion index for water shed management and agricultural land use.

Erodibility values are also evaluated in designing non-erodible earth channels and furrow irrigation systems; on the basis of critical shear stress, which is a critical basic parameter that indicates the strength of the internal force system of a soil. It is used as an index of soil erodibility. Flowing water induces a shearing force on the solid particles of the soil surface, the magnitude of which is determined to a large extent by the hydraulic condition of flow and the nature of the exposed surface. When there is an increase in the flow intensity it causes an increase in the magnitude of the shearing force.

For a stationary bed, a condition is eventually reached at which the particles on the surface are unable to resist the hydrodynamic forces and thus get dislodged and start to move. This initial movement is termed the critical condition for erosion and the hydraulic shear stress that causes this condition is the critical shear stress.

Two basic approaches are available is evaluating erodibility. They are (i) the sediment yield approach and (ii) the critical shear stress approach.

Although a soil's erodibility is a function of complex interaction of a number of its physical and chemical properties and varies often within a standard texture class, a few generalizations can be made. Usually a soil becomes less erodible as the silt fraction decreases regardless of the fact that there could be a corresponding increase in the sand or clay fraction; and the overall content of organic matter comes second in importance to particle-size distribution as an indicator of erodibility.

Length of slope, and degree of slope (L and S)

The rate of soil erosion by water is profoundly

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affected by both length and steepness of the land slope. In the soil loss equation these two effects are represented by L and S respectively, but it is more convenient and practical to consider then together in field applications as a single topographic factor.

Generally, soil loss per unit area increases as slope length increases. This is because the detachment and transport capacities of water increases as the slope length increases.

Runoff from cropland is also directly proportional to the slope gradient. However, other factors such as type or nature of the crop, the roughness or uneveness of the surface and profile saturation greatly influence this relationship.

Cover and Soil Management Factor (C and P)

In the soil loss equation the crop management factor (C) is the ratio of soil loss from land cropped under specified conditions, to the corresponding loss from clean-tilled continuous fallow.

This is a factor that cannot be evaluated independently because the combined effect of plant cover and management is influenced by

many significant interrelations. Land can be continuously cropped or cropped in rotation. In the latter case the crop sequence influences the length of time between two successive crop canopies. Further, it influences the benefits obtained from residual effects of crops and their management.

The protection from crop canopy depends on type of vegetation, the stand and the quality of growth. It also depends very much on the months and seasons. The overall effectiveness of a crop therefore depends very much on the quantity of erosive rain that occurs during periods when the crop and its management practice provide the least protection.

The soil loss ratio as described at the beginning can be generally evaluated for six crop stages or periods, as follows:

1. Ranch fallow. 2. Tillage for seedbed preparation up to 10% canopy development. 3. Establishment until 50% canopy development. 4. Until 75% canopy cover development. 5. Maturing crop, and 6. Residue stubble - Harvest to ploughing or new seeding.

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Crop Canopy

The effective energy of rainfall is reduced by the crop or plant canopy if it intercepts falling rain drops. Leaves and branches that do not directly contact the soil have little effect on the amount and velocity of runoff from prolonged rains. Water drops that fall again could have appreciable velocities, but this is usually less than the terminal velocities of free-falling, raindrops. The reduction in the amount of energy expended at the soil surface depends on the height and density of the canopy.

Leaves and branches that do not directly contact the soil have little effect on the amount and velocity of runoff from prolonged rains.

Residue Mulch

Close-growing vegetation gives rise to residue mulches and stems which are more effective than equivalent percentages of canopy cover, because mulches intercept falling raindrops so close to the soil surface that rain drops hardly regain any fall velocity. Further, they obstruct runoff flow and thereby minimize velocity and transport capacity.

Where the cover includes both canopy and mulch these two cannot be considered additive for full benefits. The impact energy of drops striking the mulch is distributed at the point regardless of the interception by the canopy and its reduction in velocity.

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5. INDIRECT EFFECTS OF EROSION

Sedimentation and Pollution

Erosion debris clog and silt up streams and channels, partially or completely, and these water ways soon loose their functions. Stretches of land may be filled or partly filled, and adjacent alluvial lands of high productivity could be severely damaged by water logging due to deposition of eroded sediments. Where precipitation is light, long stretches of drainage channels may be filled up to, or nearly to, the level of adjoining bottom land with erosion debris of rock fragments, gravel, sand and silt. These channels may have only indistinct banks, usually in the form of natural leaves. These are not usually controlled and they do considerable damage by spilling gravel and sand over adjoining productive lowlands.

Irrigation reservoirs may be quickly filled with erosional silt and sediments from neighbouring, adjacent highlands. When rivers or even harbours and bays get silted due to erosion in adjoining regions, navigation may also be hindered in certain rivers. This could have serious repurcussions on the livelihood of people, the environment and any recreational facilities that exist.

The reduction of soil productivity due to erosion and consequent loss of both top soil and plant nutrients is easy to understand, and numerous examples have been reported. Bad or unsatisfactory management practices of the past, and erosion, have their impact on the efficiency of fertilizers use on most soils. Fertility erosion and its consequent role in eutrophication, the "drying of lakes" and such problems are often reported from regions where high amounts of fertilizers are used on cash crops. While nitrogen and potassium usually get leached out of the soil, phosphorous losses are mostly associated soil erosion and eroded sediments. An nutrients collect in these lakes, large algal blooms grow, the fish and other aquatic populations diminish and lakes or water bodies develop undesirable characteristics. Over time they become swamps and finally land areas.

Sediments from erosion represent the greatest volume of wastes entering surface waters. They are washed in from farm and crop lands, unprotected forest soils, overgrazed pastures, strip mines and bulldozed urban areas. Agricultural development can increase erosion rates from four to ten times of what they would be under natural, undisturbed conditions.

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Sediments are a most pervasive form of agricultural pollutant. They get deposited in water bodies and cover fish spawning areas, clog rivers and channels, and fill up lakes and reduce light transmission in water. In addition, they carry pesticides, fertilizers, harmful chemicals, and other pollutants they have absorbed. Fine grained sediments are especially threatening because of their affinity for association with available pesticides and nutrients. Thus water quality is impaired, and navigation could also be hampered. Aquatic life is also threatened as a result of these sediments. The susceptibility of sediments to erosion and transport, and their ability to pass through many erosion and sediment control measures that may be constructed make them a real danger to the environmental balance.

The mistakes of the past should serve us lessons for us today. Sedimentation from irrigated agricultural lands, for example, has contributed to the decline of many past civilizations such as the Fertile Crescent in old Mesopotamia. Although an elaborate and extensive system of irrigation canals had been constructed they were not properly maintained, with the resultant choking of canals and accumulation of salts that were harmful for

crops. This area which has been a desert since the twelfth century has been reclaimed and repopulated by the Iraqi government in the fifties.

The Nile river draws its floods and silt almost entirely from the erosion of the Ethiopian highlands during the rains. This phenomenon while damaging the source adds fertility to the flood plains. It has been estimated that the total quantities of fine silt and soluble matter removed from half the catchment area above Aswan are 57×10^6 and 20×10^6 tons respectively.

Earthslips

Several parts of the central highlands of Sri Lanka suffer from frequent landslides, earthslips, and other types of mass movement of earth and rock. Although the areas affected are relatively small, they cause inconvenience and a great deal of damage to life, property and the livelihood of the people.

Even in certain arid regions valleys filled with alluvial material of mud and gravel can be moved considerable distances due to a sudden heavy fall of rain, when the earthfill material gets converted into a "liquid" which moves.

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The occurrence of landslides is related to factors such as topography, rock type, geological structure, rainfall and management practices in agriculture. Although the major factors are related to geology the immediate cause which triggers off a landslide is invariably excessive and continuous rainfall. Some of the serious landslides in recent years have been those at Kadugannawa, Ginigathhena, Kurunegala, Kotmale, Hunnasgiriya, Teldeniya, and Agalawatta.

In these areas mass movement of earth occurs. On dip slopes poorly consolidated, weathered material lying as thick covers above solids, unweathered bed rock, are easily moved. They also occur in steep talus or scree slopes lying at the feet of escarpments and cliffs. The central highlands, are made up of well bedded sedimentary rocks which often contain a high proportion of feldspar, and are sometimes well jointed. These rocks weather into a reddish brown clayey material known as lithomarge in which boulders of varying size are embedded. When this weathered material is saturated with water, the clayey material acts as a kind of lubricant, causing the mass of earth and rock to move rapidly down the slope due to gravity. This is especially so in the absence of a natural vegetation cover which binds and holds

this material together. The lubricative action of wet clay may act within the mass of the loose material itself, or at the junction of overburden and solid rock as a surface along which the slip can take place. Where the land is steeply sloping mass movement is rapid and takes the form of debris avalanches, earth flows and debris slides. For example, the earthslip at Waradawila (close to Rangala) in 1957, occured in seven minute and that at Kadugannawa in the same year, which took away part of the road and the vehicles on it, also lasted only a few minutes.

Of fundamental importance in areas of bedded and banded rocks is the relation between the slope of the ground and the dip of the strata. Unstable conditions exist specially where the ground slopes considerably, and relatively stable conditions exist when the slope of the ground is small. In the latter instance, however, jointing in rocks may cause instability.

On the other hand, earth movement of gentle slopes is slow and widespread though the effects are not as spectacular as rapid earth movements. Such slow movements generally result in subsidence of various kinds, spread over a span of many years. For example, at

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Nugatenne (situated on the long scree-and-talus slope of Medamahanuwara, Hunnasgiriya, the first subsidences was reported more than 60 years ago and linear or curved cracks in the ground have grown continuously in size with each period of heavy rain since 1911.

Due to natural erosion that continues steadily, the continental regions and islands like Sri Lanka would theoritically be worn down to sea level within 60 x 10^6 ears (since the beginning of the Eocene period). It has also been recognized that even at the slowest rate of erosion the materials of the earth's land mass could have eroded over and over at least eight or nine times. There is evidence that erosion and sedimentation upsets the balance of loading on the earth's crust or shell and as a consequence the outer crust could band and buckle in places. These movements of the crust lead to folding and faulting that sedimentary rocks in some places may be forced deep into the crust, while in other places they will be elevated.

6. EROSION STUDIES IN SRI LANKA

Soil erosion, the wearing away of soil from the land by the geologic agents water or wind is a normal or natural process. This is in countrast to erosion due to interference with the land by human, or animal activity, which often induces more rapid losses of soil with detrimental effects to a country and the welfare of its people.

On a global scale, tropical regions are generally the most susceptible regions to water erosion. Obviously, climatic conditions that influence relative erosion trends also reflect the vegetations and the characteristics of the soils in an area. Thus, even in the tropics, arid zones suffer least from water erosion due to the almost complete absence of rainfall (Panabokke, 1977).

In the mid and upcountry regions of Sri Lanka an appreciable proportion of soil is lost due to causes other than agricultural activities, as for example from road cuts and building sites. Soil erosion losses in different parts of Sri Lanka have been determined by several investigations and soil erosive power of rainfall in different climatic zones has been estimated by Joshua (1977).

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TABLE III ALTITUDE, MEAN ANNUAL RAINFALL, EROSIVE RAINFALL AND EROSIVITY IN SIX SELECTED STATIONS OF THE WET ZONE (KRISHNARAJAH, 1984)

Station	Altitude (m)	Mean Annual Rainfall (mm)	Erosive Rain (% rainfall 25 mm/hr)	Mean Annual erosivity KE (ft tonnes/acre) x 10^2
Galle	21	2275	62	561
Ratnapura	40	3200	56	706
Katugastota	457	1975	47	381
Badulla	677	1825	27	195
Watawala	994	4000	33	513
Nuwara Eliya	1881	1725	4	27

Measuring Soil Erosion

Water erosion is usually and easily masured by the amount of soil lost per unit area from a specific, defined land surface within a catchment or watershed. Assessment of the existing erosion within a given area in a systematic manner is a preprquisite to wise land use. It will also be a pointer to the potential erosion hazard associated with the kinds of management systems envisaged.

The early interest in soil erosion in Sri Lanka centered mostly in the hill country regions. As early as 1873 J.D. Hooker drew attention to soil erosion and irregular water supplies in this area where land was opened indiscriminately as the British plantation economy replaced the subsistence farming of the hill country for the growing of plantation crops; and the Report of the Committee on Soil Erosion, 1931 stated that tea plantations accounted for the greater part of soil erosion.

Joachim and Pandithasekera (1930) calculated the quantity of soil carried in suspension by the Mahaweli Ganga, whose watershed above the sampling point was 131,523 ha of which almost 55% was (approximately) planted to tea, to be between 32,000 and 833,000 M.T. annually. The

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average annual soil loss value from the area estimated for six years was 100 M.T. per ha.

Soil Erosion in the Wet Zone

The soils in the greater part of the wet zone are the Red-Yellow Podzolic soils (Ultisols). In regions with long, steep slopes there is much soil erosion, especially due to poor management practices.

The mean annual rainfall in the Wet Zone varies between about 1,800 and 4,000 mm. However it has been found that the intensity of precipitation deceases with increasing altitude (Krishnarajah, 1984). Table III presents the altitude, mean annual rainfall, and erosivity at six stations in the wet zone.

In the higher rainfall areas the main crop is tea, with a relatively smaller proportion of vegetables.

It is known that cultivating and planting tea had been done, up and down the slope in the first tea estate started more than 100 years ago. This would have led to considerable soil erosion when, and where the crop canopy was not widespread enough to cover the whole area in between rows. These interrow spaces therefore

could have acted as channels along which runoff water went down the hill, carrying with it whatever soil got loosened during the rains or storms. Thus much damage to soil would have occured from the beginning of tea planting in Sri Lanka, and this continues today also but to a much lesser degree.

Another factor that would have aggravated soil erosion is the practice of clean weeding using "scrapers". This practice not only exposes appreciable areas of surface soil to rain but also loosens the soil which can now easily get washed away by rain, and get transported with runoff water.

Lack of lateral drains in seedling tea fields which account for almost 85 percent of the tea area is another problem. Where they are present they are usually meant to transport water from the land rather than to conserve soil because their slope gradients vary between 1 in 7 and 1 in 30 (i.e. approximately 14 to 3.5 percent).

Scouring which ultimately results in formation of ravines and gullies with simultaneous loss of soil and exposure of tea roots is another common feature because main drains are left exposed. There is little grassy vegetation in

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many. Neither are they stone lined to provide a hard pavement. Approximately 75,000 ha of tea lands in the mid country are degraded and unsuitable for replanting. Alternate land use would be the choice on these lands (Manipura, 1971, 1972).

Rubber occupies the southwestern quadrant of the island, from sea level to around 300 m. altitude. It has been reported that nearly 60% of the annual rainfall recorded in these areas have intensities of over 25 mm/hr, although those of 100 mm/hr are also common (Krishnarajah, 1984). Thus the highest erosivity of rainfall is in the rubber growing districts. The soils in these areas are however relatively stable, and their minimum infiltration exceeds slightly, the highest rainfall intensity of the region, where rubber is planted on moderately steep to flat lands. To avoid considerable soil erosion and to conserve soil, rubber is now planted on contour platforms and terraces; and the use of leguminous cover crops protects the soil from any direct action of rain drops. The soil loss in a clean weeded rubber plantation has been calculated to be 24 MT/ha compared with one with a cover crop which recorded a loss of 0.5 MT/ha. Mulched plots showed a loss of 1.6 Mt/ha.

The mixed home gardens, common in the mid-country of the island, ideally minimizes soil loss and runoff, the maximum recorded being only 8 percent of the rainfall, and the soil loss being only 0.05 M.T/ha/ya (Krishnarajah, 1984).

Soil Erosion in the Intermediate Zone

In this region, steep slopes have been cultivated intensively in recent years, vegetables and tobacco being the main crops. Very little conservation measures are practised, and lands of over 40 percent slope have been reported to lose 70 MT/ha/ya of soil from tobacco lands; while the loss from lands under capsicum and carrot are 38 and 18 MT/ha/ya respectively (Krishnarajah, 1984).

Thus soil degradation due to erosion is a noteworthy problem in this area, especially when chena or shifting cultivation, or arable farming is practised. The best practical solution of this problem would be to encourage forest reserves on these soils.

Soil Erosion in the Dry Zone

The soils of imporatnce in the dry zone are the Reddish Brown Earths (Alfisols), the Non-Calcic

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Brown Earths and the Red and Yellow Latosols (Oxisols).

On the Reddish Brown Earths the average slope of the land is around two to three percent. However, erosion could be a problem on these soils. Although the average annual rainfall in this region is approximately 125 mm, thunderstorms with intensities of 100 mm/hr have been recorded during the period around October when intermonsoonal convectional rains are common (Krishnarajah, 1984). The intensities of much of the rainfall (almost 55%) in this region are more then 25 mm/hr, and the average infiltration rate at steady state, after four hours of saturation is 25 mm/hr. This results in high erosivity of the rainfall.

Structurally these soils are weak because although the stability of the micro-aggregates is moderately good, the bonding of the micro-aggregates into the larger aggregates are weak and ephemeral. Thus sudden wetting can lead to their rapid slaking.

In addition, these soils suffer from very rapid surface sealing due to the impact of rain drops, if the soil is bare and exposed, because they dry out rapidly and easily, and tend to get saturated also rapidly.

The above characteristics of the Reddish Brown Earths show that they are more erodible than the Red Yellow Podzolic soils of the wet zone, due to the erosivity of the rainfall and the erodibility of the soil, both of which cannot be altered to reduce erosion. Only topography, and land and crop management factors can therefore be manipulated to achieve this goal.

The choice of crops, the use of mulches, minimum tillage, use of good cover crops, construction of long, broad based terraces are some methods of minimizing erosion.

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7. CONTROL OF EROSION AND CONSERVATION OF SOIL

The primary purpose of soil (and water) conservation is to prevent soil erosion and heal the scares of erosion in locations if they are not too far advanced to respond to curative methods. In most instances this involves, changing the uses to which land is put. The first requisite to conservation of land is to decide the most suitable, and the best crop or cropping patterns (whether field crops, trees, or pastures) to suit the capabilities of the soils and the water available.

For effective soil (and water) conservation various kinds of land must be treated and used according to their capabilities and the needs. To achieve this, various conservation practices and structures known must be selected to accommodate the various kinds of land.

Although conservation measures could be used singly, on some of the more stable lands they could often be used in combinations that will mutually support one another, which therefore give greater strength, durability and confers greater productiveness to the land. In recommending them it is also important to remember that they must be used within the financial or economic limitations, and in

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accordance with the facilities available to farmers.

Equally important is the use of engineering and agonomic practices which, together, will control and conserve water and counteract the erosive action of both water and wind on the soil.

In conjunction with these two basic principles, organic matter and other plant nutrients removed from the soil must be returned to the soil. Further, adequate and optimum amounts of moisture for plant growth must be maintained, including irrigation if needed.

Use of machinery on soils must also be according to the capability and need of the land. The wrong choice will mean that both machines and land are likely to suffer.

In general, our soils like most others in tropical regions are inherently low in fertility. In some, especially those in the wet zone, the basic cations are leached off. A good proportion of the natural nutrient reserve is stored in the above-ground portions of the natural vegetation. Removal or burning of the natural vegetation cover and other biomass could cause breaks in most nutrient cycles.

Further, burning may immediately release some nutrients in readily available form, but could cause nutrient imbalances later on, or render crop uptake inefficient. This is because easily soluble nutrient elements in plant ash could easily get leached out of the root zone or get washed off with eroded sediments in runoff (Nye and Greenland, 1965). Except for the Vertisols and Andisols, most soils have low activity clays. Their buffer capacity is also low. Physical characteristics of soils are hard to generalize. They are also very difficult to manage.

In coarse textured surface soils which contain only small percentages of silt and clay sized mineral fraction aggregation is very weak. Such weak aggregates are unstable to the impact of raindrops. Quick wetting makes the aggregates to slake easily and soils develop or form crusts which on drying exhibit low permeability to both air and water. These crusts inhibit seedling emergence and establishment. In their natural state most soils are not compacted and have infiltration capacities ranging from medium to high. Mechanized land clearing and other operations that follow would soon reduce infiltration. Because these soils are easily compacted their effective "root volume" would therefore soon

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get reduced. Some physical characteristics and constraints to crop production of some soils are presented in Table IV.

Two of the most effective and commonly practised methods of controlling soil erosion is by growing cover crops and by mulching. These, by themselves may not be the most efficient in hilly and steep areas. Hence other methods have to be resorted to, some of which are described below.

1. Mechanical methods for soil conservation.

Three forms of mechanical obstructions are recommended for conserving soil (and water) by the Department of Agriculture. They are: (1) drains, (2) bunds and (3) stone terraces. Their spacing, however, depends on the steepness of the land, the steeper land requiring more of these. A guide to approximate distances, between mechanical measures recommended to conserve soil on land of varying steepness is as follows:

Degree of steepness	Spacing of mechanical measures (m)
1. Flat to gentle sloping	12
2. Moderately sloping	6
3. Steep and very steep	3

TABLE IV SOIL PHYSICAL CONSTRAINTS TO CROP PRODUCTION
SOURCE: LAL (1982)

Parameter	Alfisol (RBE)	Ultisol (RYP)	Oxisol (RYL)	Vertisol (Grumusols)
Structure	Poor	Moderate	Moderate to good	Poor to Moderate
Infiltration Capacity	Medium high	Medium to high	Medium to high	Slow
Compaction	High	High	High	Slight to moderate
Rooting depth	Shallow	Shallow	Shallow	Medium to deep
Water holding capacity	Low	Low	Low	High
Erodibility	Low	Low	Low	High
Erosion	Severe	Severe	severe	severe
Crusting	High	Low	Low	Low
Texture	Coarse	Coarse	Coarse	Fine
Clay	Low activity	Low activity	Low activity	High activity

R B E – Reddish Brown Earth
R Y P – Red Yellow Podsolic Soils
R Y L – Red Yellow Latosol

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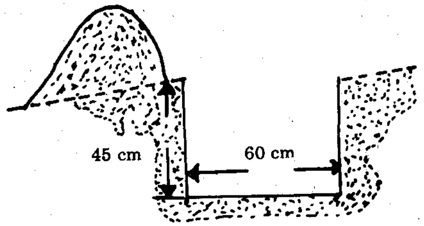

Fig. a. Section of Contour Drain

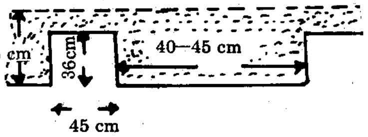

Fig. b. Section of Lock Spill Drain

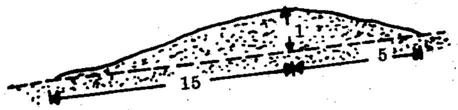

Fig. c. Broad based Earthbund

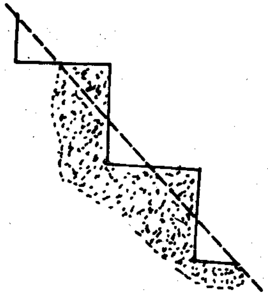

Fig. d. Bench Terraces (Section

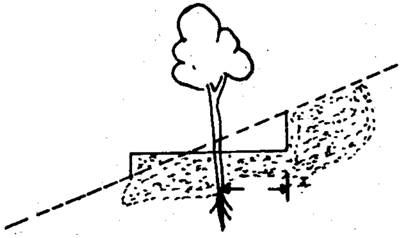

Fig. e. Individual Terrace (Section)

Fig. 2. Mechanical methods for conserving soil and water.

(a) Contour drains

This is the most commonly used mechanical device to conserve both water and soil, in which flowing water and moving water are entrapped at intervals depending on the steepness of the land (Fig. 2a). The water should infiltrate into the pore space of the soil and get stored thereafter.

The lock and spill drain depicted in Fig. 2b is a modification of the contour drain, where spill blocks, 50 cm wide and 15 cm below the surface, are cut at intervals of approximately 4.5 m. These enable water to collect in the intervening locks or troughs and enable it to get absorbed, while the soil washed with water accumulates in the troughs.

Contour drains should best be 60 cm wide and 40 cm deep and the excavated soil should be placed on the lower side of the drain.

(b) Contour earthbunds

These bunds are constructed on contours, on either on flat or very steep land, to hold back the water and the soil washed with it. Ideally the water should infiltrate into the soil after it collects at the bund.

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On flat land the bunds are very broad and are placed at longer intervals.

Broad base contour terraces approximately 6 m wide should rise 1.5 m above the base at approximately 4.5 m from its origin on the hill side and slope 2 m away from the crest towards the sloping side (Fig. 2c).

Where the land is steep bench terraces are constructed (Fig. 2d). On very steep, hilly lands, in the upcountry areas the distances between adjoining contour bunds is small and there are sharp verticle drops between one bund and the next. The height of each bund and the area of each will depend on the steepness of the land. The vertical banks between the terraces are best turred to prevent collapse.

(c) Stone terraces on contour

When large amounts of stone are available, like in some tea or rubber estates, contour stone terraces serve to conserve soil on sloping land. These would also withhold the flow of water by surface runoff and allow it to infiltrate into the soil.

Each terrace should rest on a firm foundation, at least 15 cm below the surface. The width of

the stone terrace should be 30-45 cm and its height 30 cm approximately.

Individual terraces

These are constructed around each tree on moderate and steep slopes. A circle with radius of about 60 cm is built around with the tree at the centre. Cutting into the slope and flattening would be necessary to form an artificial platform, sloping in the direction opposite to that of the natural slope (Fig. 2e). Usually the rim of the terrace on the lower side is raised above level of land on the inner side towards the slope, to about half the difference in elevation between the highest and lowest elevations before terrace construction (Fig 2e).

2. Chemical sprays and Soil Conditioners

Under certain circumstances chemical sprays have been advocated to bind the soil aggregates and to supplement the effect of other methods of erosion control, like mulching and cover crops (Alles, 1971). A chemical spray would be appropriately used, for example, in tea estates between pruning and the establishment of new growth. Another would be where annual crops are cultivated in highland areas where a

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chemical spray between seeding and establishments of vegetative cover during which crucial period the soil is exposed to erosive forces, or when practices such as mulches may not be feasible.

3. Farming Systems for Conserving Soil

Several components or sub-systems of "farming systems" have been found effective in tropical agriculture. It is not easy to develop a simple farming system applicable in general to all soils and agro-ecological environments encountered in the tropics. But these sub-systems or components could be adopted and modified appropriately for a given soil in a specified environment.

Some components that have been proved effective as measures for conserving soils are described below.

1. Land Clearing: Deforestation

The most suitable soil management practices that would minimize the deleterious effects of land clearing and development should be developed.

Deforestation or removal of vegetation have

adverse effects on physical and nutritional properties of soils, irrespective of the methods used. In addition, use of heavy machinery causes much disturbance of soil and compacts soil. These together with operations for removal of roots and stumps cause accelerated soil erosion.

Manual forest clearing is not always feasible. Further, it is expensive, slow and relatively inefficient compared to mechanical means. Hence that latter method cannot always be avoided.

Soil erosion and the degradation that results from mechanised land clearing depends on the attached equipment chosen for the purpose.

Water runoff and soil erosion as affected by various methods used in land development together with the traditional system reported by Lal (1981) and presented in Table V.

Other factors that influence erosion and subsequent degradation are (i) moisture content in soil at time of land clearing, (ii) properties of the soil including effective rooting depth and slope, (iii) the skill and training of the operator who manages the heavy machines used, and (iv) management of land after clearing.

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TABLE V EFFECTS OF METHODS OF LAND DEVELOPMENT ON RUNOFF AND EROSION.
(ADAPTED FROM LAL, 1981)

Land Development	Water Runoff (mm)	Soil Erosion (t/ha/Crop)
Traditional system	2.6	0.01
Manual Clearing- No-tillage	15.5	0.40
Manual Clearing Conventional tillage	54.3	4.60
Shear Blade No-tillage	85.7	3.80
Tree Pusher No-tillage	153.1	15.40
Tree Pusher Conventional tillage	250.3	19.60

The most appropriate method for land clearing and development would also depend on factors such as soil and climate, land-use capability, the purpose for which land is to be used (eg. whether for cropping annuals or for pastures), the nature of the crops to be grown and the tillage and cultural practices that would be adopted on the land.

2. Manageing the Soil

Agronomic methods that minimize the hazards of soil erosion are the soil management practices that should best be adapted whereever possible. These would be those that improve crop growth and vigour to provide a rapid and continuous plant canopy which will be a protection for the soil from erosion. Erosion hazards would be reduced by the following:

(a) Adequate plant density per unit of land
(b) Good crop establishment
(c) Use of balanced fertilizers and other essential plant nutrients
(d) Control of pests and diseases when necessary
(e) Planting early enough in the season
(f) Employing tillage methods that improve infiltration of water

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Some cultural practices effective in soil conservation are:-

(i) Use of crop residues mulches
(ii) In-situ production of mulches from cover crops
(iii) Resorting to no-tillage systems

3. Crop Management

The traditional systems of farming where more than one crop is grown simultaneously with another, giving rise to a multi-storey canopy of varying periods of maturity are more favourable in conserving the soil than mono-culture or pure stand crops.

Crop management practices effective in erosion control are: (i) mixed and relay cropping, and (ii) contour management.

4. Burning

Results of investigations conducted on effects of burning on tropical soils lead to the conclusion that burning, a common practice of land preparation in traditional farming throughout the tropical world, is not beneficial compared with residue mulching. Residues effectively control soil erosion, and

the favourable moisture and temperature regimes which exist under residue mulches, and the nutrients released on their decomposition benefit crop growth. In addition, it favours optimum biological activity in soils. Burning could also cause an imbalance of nutrients in the soil and accelerate the presence of soil degradation by erosion.

A disadvantage of leaving residues on soils could however be that they sometimes encourage pathogens and pests to build up large populations that destroy the crops that mulches are meant to benefit.

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8. SEA EROSION AND COAST CONSERVATION

Coastal regions, which include beaches, tidal flats, marchlands etc. comprise areas of much biological activity, diversity and productivity. They are the most continually changing zones of the earth.

Coastal Erosion

Like all sea coasts - where sea and land meet - our coastal areas are naturally dynamic zones, of no less importance than our highland areas and their associated soils, although their surface area is relatively small. Cut of the entire 1450 km of our peripheral coastline certain segments totalling approximately 395 km, are subject to extensive coastal erosion or retrogation. These include 161 km north of Colombo, 200 km south of Colombo and 32 km between Trincomalee and Batticaloa.

Generally, coastal regions are some of the most continually changing ones, where many ceaseless forces of mature have been acting from time immemorial. They are also acting now and changes are taking place constantly. Coastal erosion is primarily due to action of waves on the land. If the energy of the waves could be dissipated before they reach the land, their

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erosive action can be reduced considerably. In the last century or so, man has promoted changes or modifications in the coastal belts by his indirect influence on a number of natural processes. While in some countries his efforts have been directed to reclamation of land from the sea, in Sri Lanka it has been more towards encouraging coastal erosion with the consequent loss of valuable land. This has been particularly noteworthy since independence, in areas where the majority of the population live close to the sea shore, where their multiple activities have led to many conflicting demands and influences. During British times the laws that safeguarded the coast were more stringently applied.

The south-west coastline is now constantly retreating in contrast to that in the north-west and south-east which are generally advancing. The many "rock-exposed" islands visible off the western coast between Negombo and Matara, as for example at Beruwela, Hikkaduwa and Matara have in the distant past, been parts of the mainland which have now been separated due to the erosive action of the sea. For example, within the last 50 years, more than 100 meters of maritime land is said to have been eroded at Hikkaduwa. Marine erosion or retrogation in contrast to process

of deposition or aggradation are natural processes, but can be accelerated by human activities.

Though not frequent in Sri Lanka, cyclonic winds just ahead of a high tide can force storm waves 12 meters high into estuaries and low-lying areas. The "backwash" or retreating waters destroy crops and can even sweep away people and cattle. These phenomena lead to famine and disease.

(ii) The Causes and Conservation

Sea erosion by storm waves and tidal currents takes place mostly due to little protection afforded by material of sufficient hardness to dissipate the energy of the waves. Hence the placing of massive rocks along the sea coast in the effected areas, and the building of groyness stretching into the sea, the length of which can be calculated on the basis of available information.

Coral reefs and sandy beaches protect land from erosion as they serve to dissipute the energy of ocean waves, especially those energy-laden waves prevalent during monsoon periods. Some coasts have been classified as high-energy

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coasts, where the wave, tide, wind and other factors are intense and the processes are rapid, in contrast to low energy coasts where forces are small and moderate (Price, 1954).

Man has been associated with most of the coastal forms and processes. Apart from natural erosion, our coastlines both in the South-west and East are also adversely affected by coral mining and removal of limestone from the reef. This situation is further aggravated by removal of sand from certain areas on the coast, because lime from coral, and sea sand from the beaches have a ready market in building construction. Man in addition, has for many years removed shelfish from reefs for his food supply.

Sea levels have been rising at least four or five times during the earth's history during interglacial periods (Russel, 1940), but at present this rise seems relatively greater (Anon. 1952). In addition to this eustatic rise of sea level there has been depressions which encourage erosion in several regions.

The English who ruled us earlier, were strict about removal of beach sands and coral stones, which damage the protective reefs. Since recent times, however, the laws seem to have

been relaxed, until in 1972 a Legal Authority was set up to conserve the coastal areas from erosion hazards. However, nothing useful or practical happened until October 1976 when draft legislation was introduced in the National State Assembly (but the prorogation of Parliament stalled and delayed the process).

In 1978 provision was made in Budgetery Estimates, for Rs. 9.63 million, to implement the new Coast Conservation Law and to prepare a Coastal Resource Development Plan, the purpose of which was to provide a consultancy on coastal engineering problems, to plan, to investigate and to construct coast protection schemes. Several foreign coastal engineering experts have advised the Government of Sri Lanka. The more recently set up Cental Environmental authority would also be interested in conserving our coasts.

Destruction of the protective reef can occur due to ecological reasons as well. One explanation is that a variety of starfish which has multiplied itself to large numbers feed on the organisms responsible for reef building. This ecological imbalance could have been brought about because the numbers to some organisms that predate on this starfish.

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Reef building organisms such as shellfish and corals could be killed even directly due to pollution, as for example by oil pollution from tankers and ships, or industrial pollutants because most effluents are diverted directly to the sea, or ultimately find their way into the sea, via streams, rivers etc. Mining near the coast or inland, and oil drilling in coastal waters, although not applicable to Sri Lanka, can also contribute to the pollution problem.

In areas where fresh and sea water mix, the destruction of mangroves either due to pollution or development can be another cause for accelerated sea erosion. Over population of birds and other animals can also cause destruction of these mangroves. Some of these mangrove areas may be even below sea level and therefore the sea can easily eat into the mainland.

Dune - huilding, and dune - holding plants play an important role over extensive areas of land. Thus, stabilization of dunes and upper beaches is important. Although mechanical methods such as retaining walls and revetments are employed, the most effective have been the use of natural vegetation and the plantings of herbs, shrubs and trees, and improving the natural vegetation in accordance with the principles of ecology (Kutz,1942).

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9. CONCLUSION

Conservation, in very broad terms can be referred to the steps or measures necessary to ensure continuing supplies of materials on which the economy of a country depends to a greater or lesser extent. These measures should include the efficient use of such materials and the prevention or avoidance of their premature or irretrievable abondenment.

In a country like Sri Lanka where soil erosion is a serious problem over an appreciable part, it is extremely important that farmers and others who live by the soil be made aware of this hazards of this problem: both its short term and long term effects.

The Soil Conservation Act. No. 25 of 1951 (Gorrie, 1952) has not been as effective as it was meant to be. Whatever soil conservation that was practised was due more to the efforts of the Staff of the Soil Conservation Division of the Department of Agriculture, and their counterparts at the crop research stations viz. T.R.I., R.R.I. and C.R.I.. The recently established Central Environmental Authority would perhaps enforce the laws of Soil Conservation more effectively in future.

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