Natural Resources Series - No. 2

SOILS
and
AGRO-ECOLOGICAL ENVIRONMENTS
of
SRI LANKA

C.R. Panabokke

Natural Resources, Energy and
Science Authority of Sri Lanka

C.R. PANABOKKE

Dr. C.R. Panabokke received his Ph.D. in Soil Science from Adelaide University in 1956. He has provided leadership to land and water management research in Sri Lanka for over 25 years as Head, Land Use Division (1960-1974) and Director of Research, Department of Agriculture (1974-1979). He was Director of Agriculture (1979-1982) and later served as Senior Research Fellow at the International Service for National Agricultural Research (ISNAR) at the Hague. He was a member of the Board of Governors of the International Board for Soil Research and Management (IBSRAM) from 1983 to 1989. He now serves part time with the International Irrigation Management Institute (IIMI) as a Senior Research Associate. He received the National Science Council award for outstanding scientific research in 1982; and the Presidential Vidya Jyothi honour in 1986. He was conferred the D.Sc (Honoris Causa) by the University of Peradeniya in December 1994.

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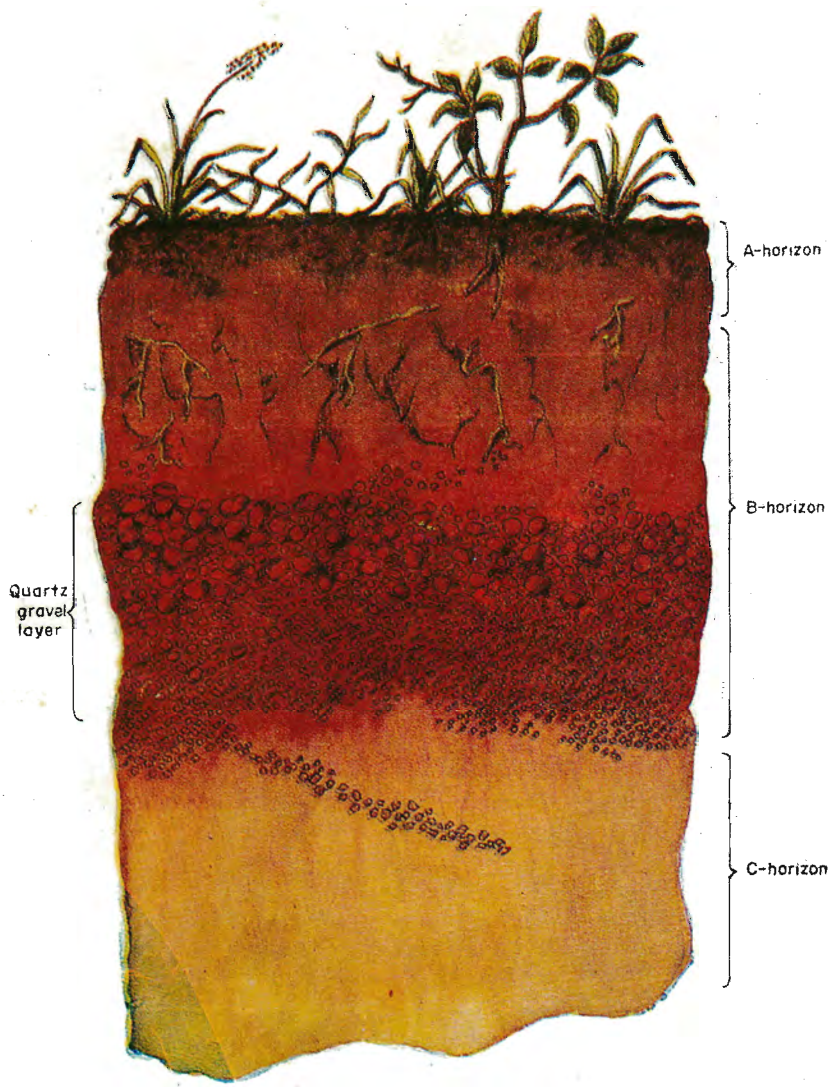

Plate I: Profile of a Reddish Brown Earth in the Anuradhapura District

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By

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FOREWORD

The Steering Committee on Natural Resources of the Natural Resources, Energy & Science Authority of Sri Lanka has undertaken the publication of a series of documents on various topics on natural resources such as economic geology, climate and water resources. This assignment on Soils of Sri Lanka has been given to none better fitted for this task than the author.

Dr C.R. Panabokke has by training and experience in many continents and countries such as Africa, Australia, Central Asia, USA, Russia and China, a wide knowledge and understanding of soils. No less is his direction of the Soil Survey in Sri Lanka. He has therefore been the obvious choice to write this manuscript which is an authoritative reference on the different aspects of the country's soil resources. In the preparation of this work, he has utilized extensively from various sources to illustrate the text.

The different chapters are descriptive of the full spectrum of soil science. The text contains up-to-date information as a reference for researchers in this field of study as well as policy makers.

NARESA appreciates the tremendous efforts of Dr Panabokke who has succeeded in this most valuable contribution to popularizing science.

Prof. Priyani E. Soysa
Director General
Natural Resources, Energy & Science Authority

This book is dedicatd to Dr Ernest Abeyratne, scientist, humanist, world citizen and friend who introduced the author to the study of soils in the field, in the catenary landscapes around Maha Illuppallama.

"It is not for you alone to complete the task, but neither are you free to evade it".

A first century B.C. Hebrew saying.

PREFACE

The request from NARESA to write this book came at a time that I was best prepared to undertake a task of this nature. Having almost left the field of active soils research around the mid-eighties, the period that followed provided me ample opportunity to quietly reflect on the studies on soils as a natural resource, carried out by a team I was part of, over a 25 year period. My part time attachment to the International Irrigation Management Institute (IIMI) as a Senior Research Associate in recent years also provided the proper environment and sustenance for undertaking this task.

This publication is not intended to be a straight compilation or an updating of available information on the soils of this country. Rather, an attempt has been made to give a sense of meaning and substance to the soil resources of Sri Lanka as observed and perceived through the experiences and understandings of a team of colleagues who had worked closely with me over a 25 year period in the Soil Survey of Ceylon (later Sri Lanka).

Drs K.A. de Alwis, W.D. Joshua, S. Somasiri, N.S. Jayawardena and the late Sunil Dimantha were my senior colleagues. They were ably assisted by soil survey party chiefs Messrs. Ed. Jayasooriya, Piyasiri Hettige, N. Nadarajah and the late S. Ponnuswamy. Excellent cartographic support was always provided by Mr K. Sunil Fernando.

The scope and purpose of this publication as well as a guide to its use is outlined in chapter 1. It is mainly addressed to those readers who have an interest in advancing their understanding of our soils from the standpoint of a natural resource. In this sense, it also conforms to the stated objectives of NARESA's series of publications pertaining to the natural resources of Sri Lanka. The first volume in this series was on the Economic Geology of Sri Lanka authored by Dr J.W. Herath, and this publication is the second volume of this series.

The main orientation and contents of the latter chapters of this book underwent several changes after I had a well considered response to the initial drafts of the chapters from Dr Wasantha Punchihewa, a general reader, and from a different discipline. He advised that a greater emphasis be given to agro-ecological considerations rather than to soil landscapes, because the former had a greater contemporary relevance to the needs of our time, especially in agriculture. This has, in retrospect, proved to be very wise counsel.

Several persons have contributed in many important ways toward the realization of this publication in its present form. Ms. Sumedha Abayaratna very patiently bore the tedious task of typing the whole manuscript despite frequent revisions, additions, and deletions. Dr R. Mahindapala, then Director of the Coconut Research Institute (CRI), recognized the scientific value of this endeavour and provided me considerable institutional cartographic support that essentially gave the "kick start" to commence this work, and he also extended the much needed patronage at the early stages. Mr K. Sunil Fernando provided the best of his cartographic skills in the preparation of the figures on soilscapes and transects of land systems. Mr L.D. Jinadasa gave much of his time in lettering and compiling the many diagrams, figures, and maps. Mr L. Amarasinghe helped in many ways in assembling diverse material. Mr Nimal A. Fernando very kindly undertook the task of editing the whole manuscript within a short period.

The early realization of this book in its printed form was largely due to the diligent efforts of Ms. Anusha Amarasinghe, Assistant Director, NARESA, who attended to every aspect of the pre-press work on the text, figures, and tables and the printing. I owe her a special word of appreciation, as much as I do to the printing staff of NARESA who did a very expeditious job.

C.R. Panabokke

Nawala
Rajagiriya
October 1996

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CHAPTER 1

Introduction

1.1 SCOPE AND PURPOSE

This publication deals with soil as a natural resource. Its main aim is to help improve our understanding of the essential substance and nature of the different kinds of soil found in this country and their variation or variety across a wide range of environments and landscapes.

It also attempts to bring together in a single volume much of the significant information generated by various researchers over the last four decades in their studies on soil as a natural body. It should, however, be borne in mind that this approach does not, in any way, imply that studies conducted in other disciplinary areas of soil science such as soil chemistry, soil physics, and soil fertility are considered less important. In order to keep this publication within a specific focus, and to maintain a balance in its content, such an approach had to be adopted.

It was not possible to accommodate aspects of soil and land management in this publication because of the very wide range of subject matter that would have to be considered. Such a task, which could bring together all available information in this area of soil management, is left to a separate publication. The basic knowledge provided in this publication does, however, provide the essential background material, which when properly interpreted would form the basis for formulating appropriate practices in soil management.

With the rapidly growing interest shown by various environmental groups and agencies in sustainable resource management, the need for a reference text that deals with soils as a natural resource acquires a special significance. Such a text should aim at providing environmentalists the core information on our soils that would enable an objective analysis and interpretation of issues, based on principles of reasoning rather than resorting to a comprehensive coverage that tends to cloud or distort the central issues. It is expected that this publication would provide a major part of this essential core information.

Other equally important reader groups to whom this publication is addressed are students of natural and environmental sciences, undergraduate students of the national universities, and postgraduate students engaged in field research. It also accommodates the general requirements of readers interested in various aspects of the natural history of the country.

A proper study of the soil should really begin in the field. It is remarkable how much one could study about a soil in the field with the aid of a spade, penknife, and a cheap pocket lens, at a new road bank cut or trench or at the site of excavation of shallow wells. Although a small country, Sri Lanka has a rich diversity of soils. Some of the more important and widespread soil groups of the tropical world are found in this country, while at the same time there are some soil groups that are unique to the country. A keen observer travelling by road or rail can never fail to be impressed by the striking variations in colour and other features of the soil that can be observed on road cuts and on banks of homesteads in sloping land. Identifying the different soils of this country can become as absorbing a hobby as the study of bird and plant life.

1.2 GUIDE FOR THE GENERAL READER

This publication is organized in eleven chapters. The general reader would find it convenient to select for reading the chapters that suit his or her special needs or interests. *Chapter 7* on agro-ecological environments of Sri Lanka, and *chapter 9* on land evaluation and land suitability, could be read and understood with minimum reference to the other chapters of this book. The rest of the chapters are, however, so closely interrelated in many ways that they need to be taken together. The final chapter, *chapter 11*, addresses one of the more frequently discussed contemporary concerns of our times, namely, sustainable management of land resources. In order to properly appreciate the significance of the contents of this last chapter, the reader should possess a good grasp of the general principles that have been discussed in the preceding chapters.

Chapter 2 provides the setting for understanding the main environmental factors that influence or govern soil formation in this country. Since the subsequent chapters deal with the relationships of soils to various climates, parent materials, and landforms, these environmental factors have been described and explained at a relevant level of detail.

Chapter 3 should be considered as compulsory reading because it explains both the evolution of a soil profile and how the morphology of the soil profile constitutes the main basis of soil identification, characterization, and classification.

The main substance of this publication is contained in chapters four and five. *Chapter 4* attempts to bring together, in a selective and concise form, a large body of information and knowledge gathered over a period of over three decades by the National Soil Survey of Sri Lanka. The soils of Sri Lanka have been discussed in a manner that would help to bring out their relationships to the environmental factors that govern soil formation in this country. For the benefit of the specialist, the placement of the country's great soil groups according to Soil Taxonomy (1975) and FAO World Soil Resources Report (1993) is also included.

It should be borne in mind that in Sri Lanka, more than in any other tropical country, a true appreciation of the soils derives from a proper understanding of the different soil-landscape relationships. Hence the special importance of *chapter 5*, which discusses seven soil landscape units or soilscapes of the dry zone and four soilscapes of the wet zone.

The strengths and weaknesses of the different systems of soil classification, and the evolution of soil classification in this country from the early classification of Joachim (1945) are discussed in *chapter 6*.

As stated earlier, *chapter 7* stands by itself and could be considered an expanded explanatory text for the revised agro-ecological regions (AER) map of Sri Lanka. Such an expanded version has not been published before, and this could therefore be taken as a near complete guide and supporting text to the AER map of this country.

A separate chapter, *chapter 8*, has been devoted to the paddy soils and to the pioneer work done in this country in the approach to understanding and characterizing paddy soils in the framework of land systems. Since this study is believed to be unique to rice-growing Asia, it is considered highly worthy of inclusion in this publication. Moreover, because of the pride of place given to paddy (rice) and paddy lands from ancient times in this country, a separate chapter could be justified.

Chapter 9 is essentially meant for the specialist and may not interest the general reader who could conveniently afford to omit it. It would be of special importance and relevance to researchers and policymakers in the tree crop plantation sector.

Chapter 10 on soils and agriculture should be considered as one of the more important chapters in this book, both for the general reader as well as the agriculture extension specialist and land use planner. The latter groups would find it extremely useful in the interpretation of soil information for making recommendations on crops and land use practices.

Finally, *chapter 11* discusses the very contemporary topic of sustainable management of soil and land resources in terms of the accepted definitions and approaches, and it also sets out a preliminary framework for addressing the management issues of the different agro-eco-soilscapes of the country.

A glossary of selected technical terms is given at the end of the text; and the formative elements of the names of the major soil groupings and soil units according to the FAO-UNESCO Soil Map of the World are given in Appendix I.

CHAPTER 2

The Environmental Background

2.1 CLIMATE

According to the modern scheme of climatic zonation employed in the World Soil Resources Map (1991), the wet zone of Sri Lanka falls within the *humid tropics* and the dry zone within the *seasonally dry tropics*. A small section in the northwest and southeast of the island falls within the *semiarid tropics*.

Four basic types of rainfall, namely, monsoonal, convectional, cyclonic and orographic, are identified in the country. These occur singly and in combination.

The southwest monsoon (summer monsoon) is from May to September. Precipitation occurring with these winds is confined entirely to the windward side of the hills in the southwest sector of the island. These southwesterlies blow over the central mountains and continue as dry winds across the eastern sector of the island.

The northeast monsoon (winter monsoon) is from December to February and northeast monsoonal winds are weaker than the southwesterlies. The amount of rain associated with them is less because these winds gain moisture only from the Bay of Bengal. The rainfall is, however, more widespread than that occurring during the southwest monsoon, and it spreads to the southwest part of the island as well.

Rainfall during the two intermonsoonal periods, March-April and October-November, is mainly convectional and occurs over the whole island. These rains come as short duration high intensity thunderstorms, and occur mainly in the afternoons and evenings.

During October-November, the island is also influenced by depressions that form in the southwest Bay of Bengal and also in the southeast Arabian Sea. Major floods are normally experienced during the occurrence of deep depressions.

The mean annual rainfall in Sri Lanka varies from 2,500 mm to over 5,000 mm in the southwest of the island, while in the northwest and southeast the annual rainfall is less than 1,250 mm. The mean annual rainfall for the island is shown in figure 1. Rainfall over most parts of the country follows a bimodal, seasonal pattern for the year.

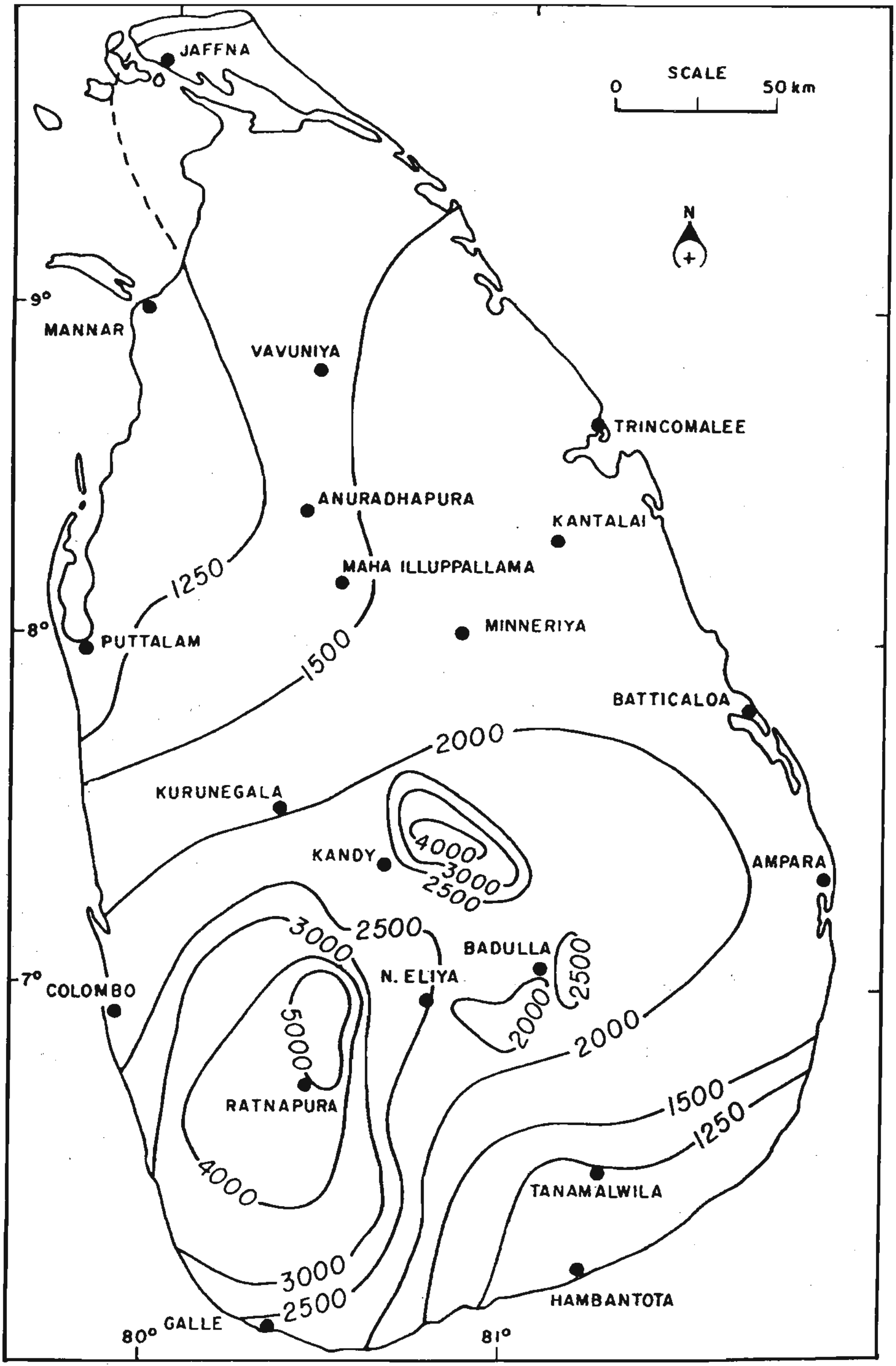

Figure 1: Mean Annual Rainfall (Isohyets in mm). (M. Domros 1974)

The division of the island into two main geographic zones, the dry zone and the wet zone, was widely recognized up to 1956. During the period 1956-61, when studies were conducted by the Ceylon Colombo-Canada Plan Project surveys on land use, forestry, hydrometereology, and soils, a transitional intermediate zone was recognized as shown in figure 2.

Over 50 percent of the days of the year is rainy in the wet zone, and this may increase up to 70-75 percent in the wetter areas. Less than 25 percent of the days of the year is rainy in the dry zone, and about 66 percent is rainless.

The mean annual temperature of the island is shown in figure 3. The regional differences in temperature are mainly due to altitude, with the temperature falling about 1°C for every 150 m rise in elevation. Diurnal variation in temperature is distinctly higher than the annual variation, and is very marked during the months of February and March.

There is a marked seasonal variation in the Class A pan evaporation (evaporation from a free water surface) within the island. In general, in the dry zone it is around 6 mm per day during the dry season, and about 3 mm per day during the wet season. In the wet zone it is between 3.5 and 2.5 mm per day, while in the higher elevations of around 2,000 m it is between 2.5 and 1.5 mm per day.

Further aspects of the climate in relation to agro-ecology are discussed in chapter 7.

2.2 PHYSIOGRAPHY

One of the best descriptions of the general physiography of Sri Lanka is given in chapter 4 of Cooray's *Introduction to the Geology of Sri Lanka* (1984). Selective extracts from this chapter are reproduced here to capture the essential features of the physiography as far as these relate to the soil landscapes of the island.

> *The physiography of Sri Lanka can best be described as consisting of a central mountain mass, the Central Highlands, rising in a series of tiers or ramparts from a low, gently undulating plain surrounding it in all sides and extending to the sea. One could recognize three well-marked plains of erosion or peneplains cut in the rocky framework of the island.*

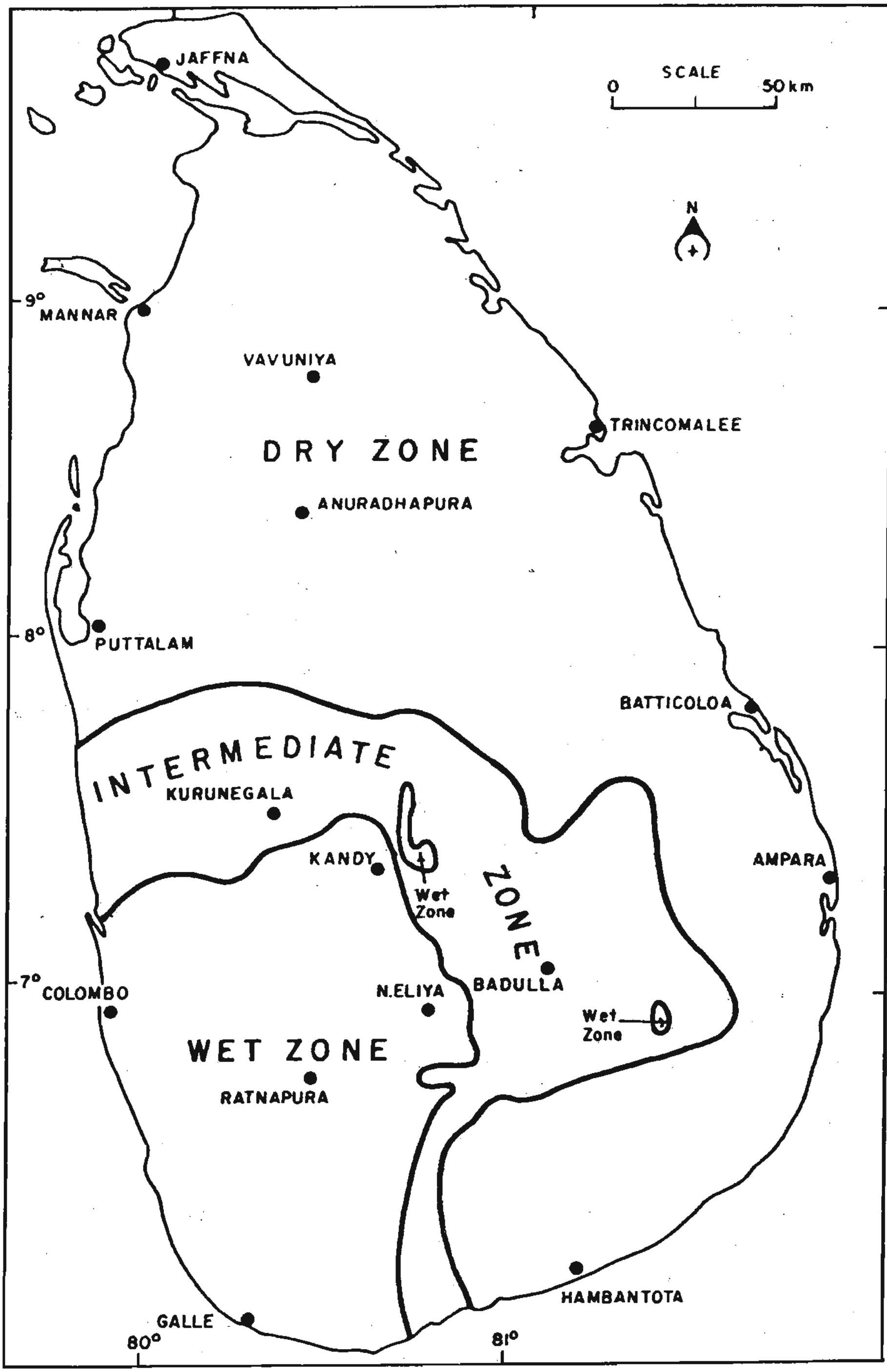

Figure 2: Demarcation of Wet, Dry and Intermediate Zones.

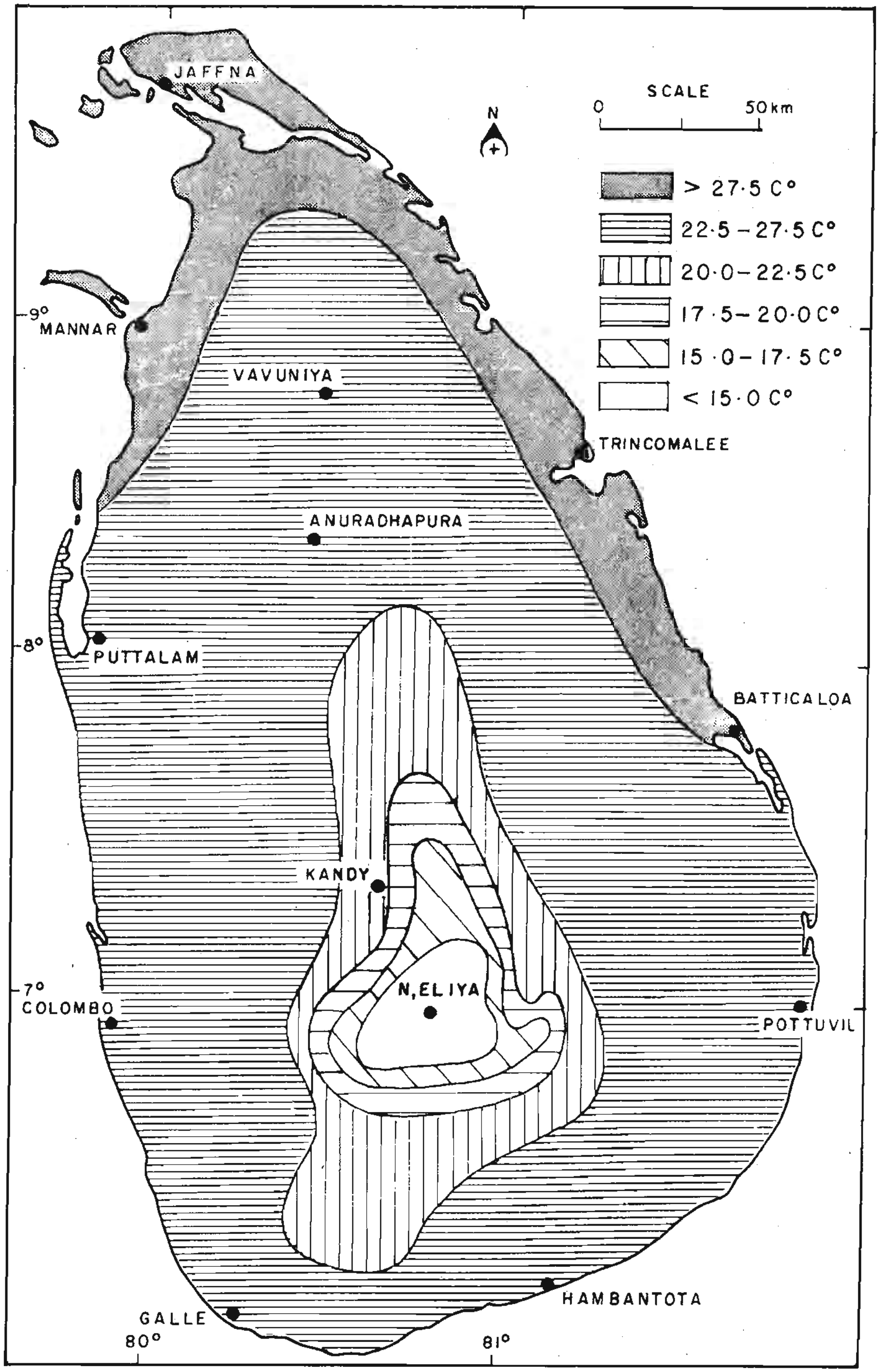

Figure 3: Mean Annual Temperature (R. Kannangara 1982).

The lowest peneplain surrounds the central hill country on all sides and is a gently undulating mantled plain stretching down to the coast. Rising from this inner edge in a steep step of about 300 m is the middle peneplain (see figures 4 and 5) with a maximum elevation of about 800 m above sea level. Within it and rising from it in another steep step of 1,000 to 1,300 m is the highest peneplain at a general level of about 2,000 m but rising in places to 2,300 or 2,700 m. Though deeply dissected by river valleys these peneplains are recognized by the fact that the summits of the hills and ridges show a general accordance of levels (Cooray 1984).

The respective elevations of the 3 peneplains are:

Lowest peneplain	—	0-125 m
Middle peneplain	—	125-750 m
Highest peneplain	—	750-2,500 m

The principal physiographic regions that make up the island are the above three peneplains and the coastal plain.

The lowest peneplain is the result of millions of years of subaerial weathering of the ancient, highly folded landmass of crystalline rocks, which must have been very different in appearance from what we see now. During this time, tens of thousands of feet of crystalline material were removed, and only the roots of the great mountain chains that once existed now remain. Further, the processes of erosion have not only destroyed most of the hills but have also filled the intervening valleys with detrital material.

There are also, in the lowest peneplain, thousands of low, bare rock mounds or turtle backs, whose form is due largely to a weathering process known as exfoliation (Cooray 1984).

These are now referred to as Rock Knob Plains in soil maps.

The middle peneplain is best observed from the eastern and southern parts of the island.

Inland from the coast the land rises very gradually to about 100 m until it reaches the foot of an escarpment generally about 300 m high, which separates the lowest peneplain from the middle peneplain. The escarpment is continuous in many places, as in Minipe and Kongala areas, but elsewhere it is deeply indented and irregular where rivers have cut back into the wall and destroyed its continuity while enlarging their drainage basins (Cooray 1984).

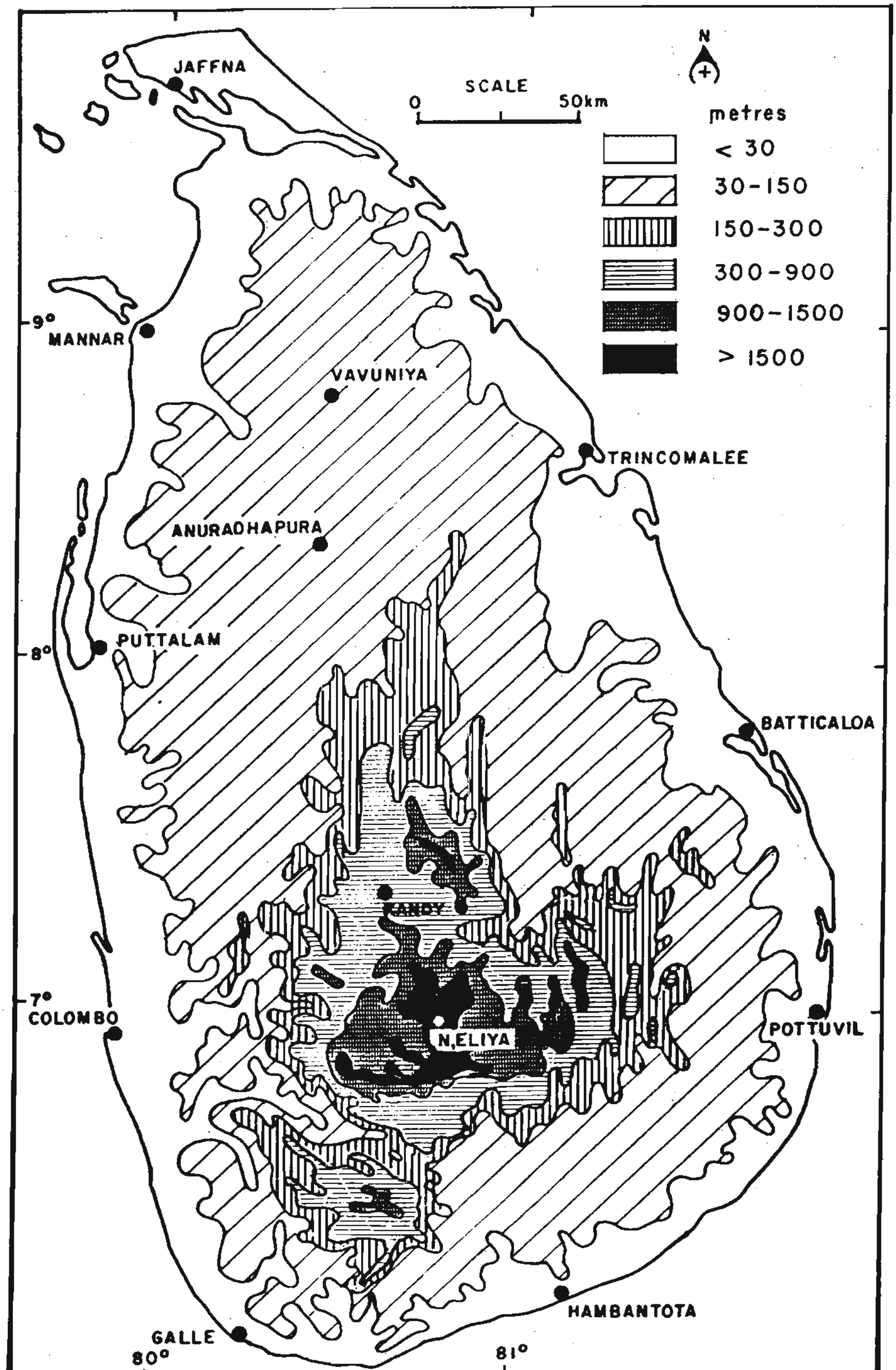

Figure 4: Generalized Relief Map of Sri Lanka.

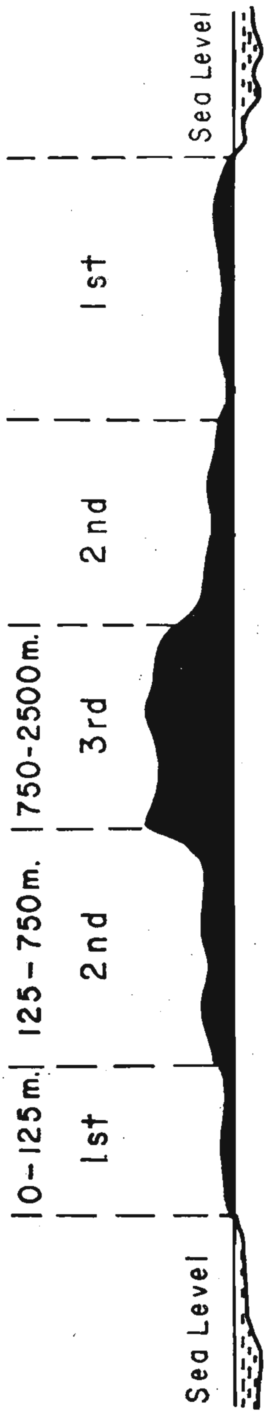

Figure 5: Diagrammatic Section Showing the Three Peneplains.

The highest peneplain is less like a peneplain when compared with the lowest and middle peneplains.

> *It is more a complex of plateaus, mountain chains, massifs and basins within each of which a general erosion level can be recognized (see figure 6). Both the High Plains and the Uva Basin are made up predominantly of easily weathered, feldspathic metamorphic rocks and this is the cause of the soft, rounded landforms, and the deep, clayey soil found here. The appearance of "flatness" of the Hatton Plateau is largely due to the nearly horizontal attitude of the rocks within much of the area (Cooray 1984).*

Owing to the many factors associated with the tectonic uplift of the mountain massifs, the middle and highest peneplains contain many step like surfaces at different elevations. Each step represents a more or less dissected old surface separated from the next one by a complex pattern of hills and valleys, both structural and tectonic.

> *The coastal plain of the country is largely made up of sedimentary deposits formed during the last two million years of the island's history. These occur in a coastal belt that is narrow in the southern half of the island but widens considerably northwards of Negombo on the west coast, and Batticaloa on the east coast. The quaternary deposits of the northwest coastal region between Negombo and Puttalam have recently been recognized as belonging to two major groups. One is a younger group occupying the belt of barrier beaches and bars, sand dunes, lagoons, and estuaries adjacent to the coastline. The other is an older group made up of red earth, basal ferruginous gravel, and terrace gravel, which form the slightly higher land immediately east of this belt.*

2.3 GEOMORPHOLOGY AND LANDFORMS

In describing and discussing the soils and soil landscapes of Sri Lanka in chapters 4 and 5, reference will be made to the relevant features of the landscapes on which the soils are distributed. Our present understandings of the geomorphological processes in this country are not advanced to a point that would enable us to demarcate the distinctive geomorphological regions that make up the country. In respect of the soil cover of the island, however, one could recognize three broad geomorphological divisions. The coastal plain could be regarded as a *depositional surface*, while the three peneplains could be regarded as *planation surfaces*. Located between the respective planation surfaces one could also recognize dissected *transitional surfaces*. These terms will be used to describe the broader geomorphological features of the landscape.

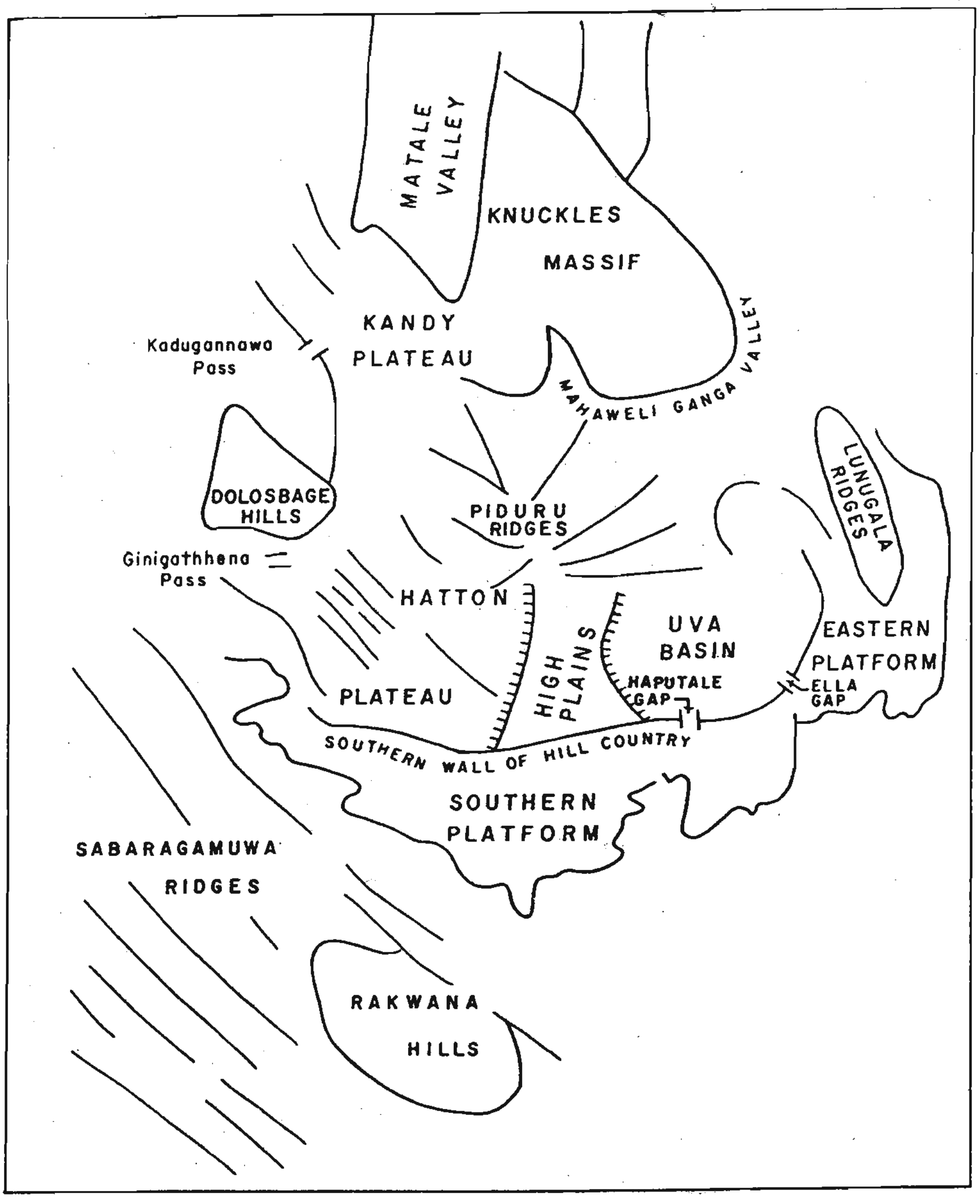

Figure 6: Physiographic Regions of the Hill Country (E. Cook 1931).

At a more definitive lower level, the *landform* will be used to characterize the nature of the landscape. A landform may be defined as a unit of land that is homogeneous from the point of view of origin and morphology, or heterogeneous with a repetitive pattern of two or more landscape elements. Landforms are defined and described in terms of structure, process, and stage, the three principal factors influencing the form of the earth's surface.

The following 11 landforms are the more important and widespread ones recognized in the country. Landforms 1 to 5 are mainly present in the middle and highest peneplains, and landforms 6 to 8 are mainly present in the lowest peneplain. The coastal plain is made up of landforms 9 to 11.

1.	Mountain	
2.	Escarpment	
3.	Hill and Ridge	Middle and Highest Peneplains
4.	Ridge and Valley	
5.	Hill and Valley	
6.	Mantled Plain	
7.	Rock Knob Plain	Lowest Peneplain
8.	Erosional Remnant	
9.	Flood Plain	
10.	Coastal Plain	Coastal Plain
11.	Sand Dune and Beach	

Terminologies of landforms 1 to 5 and 9 to 11 are well known in landscape descriptions and need no further explanation. A brief description of landforms 6 to 8, which acquire special significance under Sri Lankan conditions, is given below.

The term *mantled plain* is used to designate the gently undulating to rolling plains of the lowest peneplain of the dry zone, which have a mantle of residual materials derived by weathering from the underlying bedrock. The mantle consists of this residuum and the soil profiles developed in its upper part. This landform exhibits variations that are determined partly by the underlying rock type and geological structure, partly by the erosion and weathering processes that have acted on the parent rocks, and partly by the length of time that these processes have been in operation. Four topographic classes of mantled plain have been recognized: (1) level class, (2) undulating class, (3) rolling class, and (4) hilly class.

The term, *rock knob plain*, is used to designate those plains that are characterized by a rough and broken relief of extensive tracts of low bedrock exposure. These are also confined to the lowest peneplain of the dry zone. The rock exposures are usually rounded and take the form of low domes and ridges. The bases of the outcrops are stony and bouldery because of the accumulation of exfoliated debris from the higher rock exposures.

The term *erosional remnant* is used to designate the isolated bedrock-controlled hills and ridges that rise steeply from the general level of the mantled plain. These are also referred to as inselbergs in geomorphological literature. These hills may consist entirely of bare rock or they may have a thin soil mantle.

2.4 GEOLOGY

The greater part of the island is made up of highly crystalline, non-fossiliferous rocks of Precambrian age belonging to one of the most ancient and stable parts of the earth's crust. The main occurrence of sedimentary rocks is along the northwest coast of the island, which is built up of limestones of the Miocene age. The main formations present in the island and their ages are shown in table 1. A simplified geological map of the island is shown in figure 7.

Several dolerite dykes, small granitic bodies, and a series of pegmatites have intruded into the Precambrian rocks. Two small occurrences of Gondwana sediments (Jurassic) are located in the northwest of the country at Tabbowa and Andigama. The Miocene limestone formations of the Tertiary system occur in the Jaffna peninsula and the northwest of the country, and a small outcrop of Lower Miocene at Minihagalkande in the extreme south.

On the basis of lithology, structure, and age, the Precambrian rocks have been subdivided into 3 major groups (Cooray 1984): (1) Highland Series, (2) Southwestern Group, and (3) Vijayan Complex (figure 7).

The Highland Series is composed of metasediments and closely associated charnockite gneisses. The metasediments comprise quartzites, fine-grained acid gneisses, granulites, calc gneisses, marble and type khondalite, which is a sillimanitic-garnet-graphite schist. The Highland Series occupies a broad belt running across the centre of the island from southwest to northeast, and it thus includes the whole of the central hill country and part of the northern plain (figure 7).

TABLE 1: Main Geological Formations of Sri Lanka

ERA	SYSTEM/ PERIOD	SERIES/ EPOCH	PRINCIPAL FORMATIONS
CENOZOIC	QUATERNARY	Holocene Recent	Younger group - alluvium, beach and dune sands, lagoon and estuarine clays
		Pleistocene	Older group - red earth, terrace gravels, ferruginous basal gravels
	TERTIARY	Miocene	Jaffna limestone, Minihagalkande beds
MESOZOIC	JURASSIC		Tabbowa beds Andigama beds
PALAEOZOIC	absent		
ARCHAEOZOIC	PRECAMBRIAN		**Vijayan Complex** gneisses, migmatites, granitoid rocks **Southwestern Group** metasediments, charnockitic gneisses, granitic gneisses **Highland Series** metasediments, charnockitic gneisses

(Adopted from Cooray 1984)

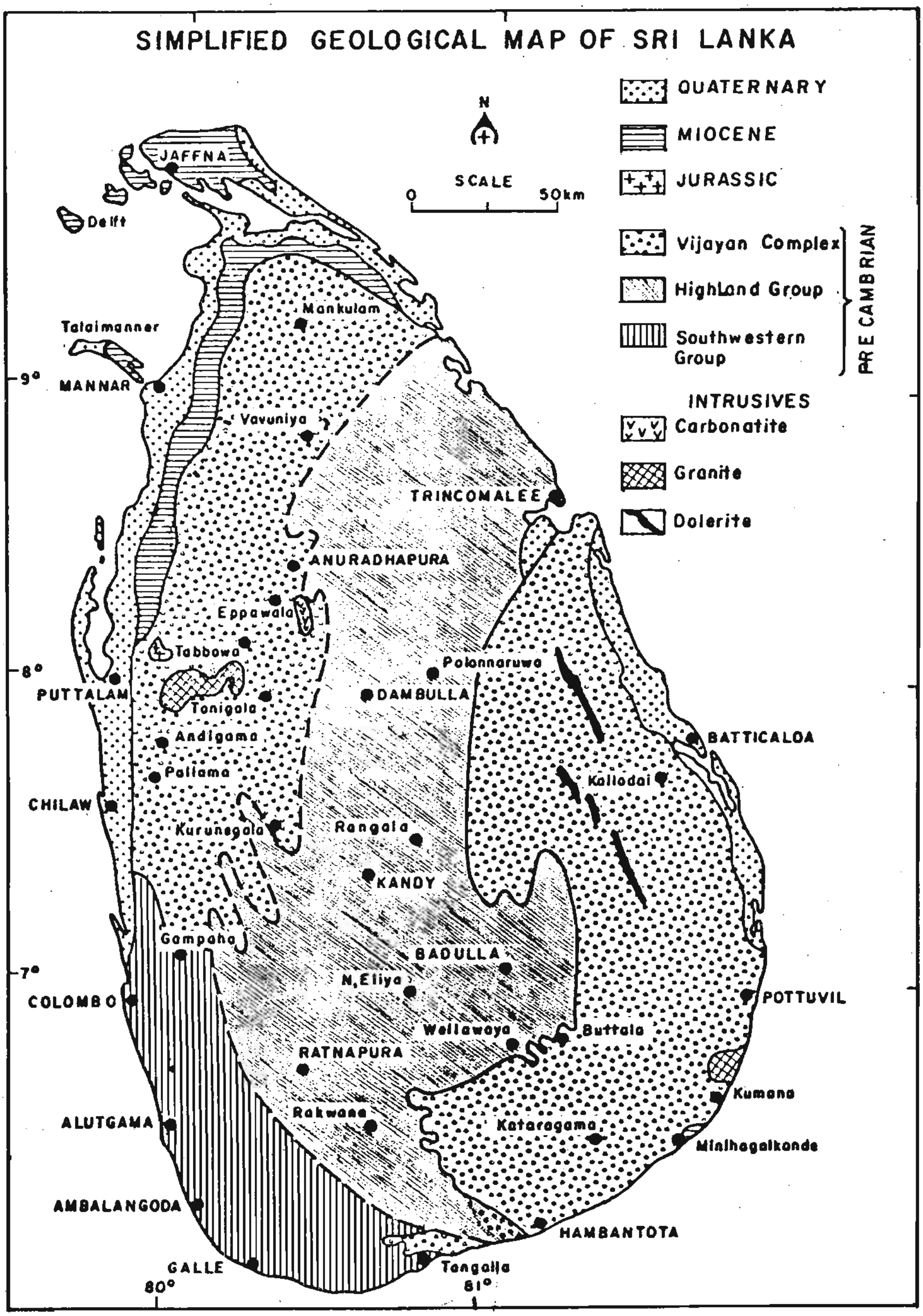

Figure 7: Simplified Geological Map of Sri Lanka (Cooray 1984).

The Southwestern Group occupies the southwestern sector of the island (figure 7) and is made up of schists, gneisses, and granulites of metasedimentary origin, as well as migmatite and granitic gneisses. Both its lithology and metamorphic history differentiate it from the Highland Series.

The Vijayan Complex occupies the lowlands to the northwest and southeast of the Highland Series (figure 7). They are sometimes referred to as the Western Vijayan and Eastern Vijayan. The main rock types include a variety of gneisses, migmatites, and granitoid gneisses including charnockite gneisses. Numerous pegmatite and dolerite dykes have intruded into the crystalline rocks at various times between the Precambrian and Tertiary eras. The more complex landforms and soil distribution patterns that are encountered in this area could be partly explained by the following extract from Cooray (1984):

> *Unlike in the Highland series, the Vijayan rocks are seldom uniform for any length, and are highly contorted and folded. They seem to have been pushed and shoved about in several directions by the forces of pressure.*

Earlier it was thought that all the crystalline rocks were formed in one geological episode, but new evidence shows that the crystalline rocks were formed in two different periods. The Highland Series is believed to have been formed during the mid-Precambrian period, and the Vijayan Complex during the early to mid-Palaeozoic period.

2.5 SOIL PARENT MATERIALS

It should be emphasized that under the landscape formation and climatic conditions in Sri Lanka, the occurrence of soils formed on in-situ residuum is very rare. Most commonly the parent materials of the soils have been dislocated considerably, and thus could with reason be considered as colluvium or colluviated residuum.

Groups of parent materials are distinguished mainly on the basis of their importance in regard to the soils that are formed on them. Thus, the categorization of parent rocks is not a systematic petrographic one, since petrographically very different rocks may produce similar soils and vice versa.

The main groups of parent materials distinguished and used in soil descriptions in subsequent chapters are:

- Residuum and colluvium from intermediate and basic gneisses
- Residuum and colluvium from acid gneisses
- Residuum and colluvium from schistic and micaceous gneisses
- Semi-recent and old alluvium
- Recent alluvium
- Beach and dune sands
- Montmorillonitic clay from alluvium

2.6 NATURAL VEGETATION

The principal types of natural vegetation found in the wet and intermediate zones of the island are tropical evergreen forest, tropical semi-evergreen forest, montane temperate forest, and submontane or mid-country tropical evergreen forest.

Tropical evergreen forests are confined to the southwest sector in the lowland wet zone where the annual rainfall is above 2,500 mm, and where only one or two months have averages of less than 100 mm rainfall. These forests are luxuriant in growth, the evergreen trees reaching about 20 to 25 m in height and forming a dense canopy.

Tropical semi-evergreen forests are intermediate in structure between tropical evergreen forest and dry evergreen forest, and are found mainly in the intermediate zone where the mean annual rainfall is between 1,750 mm and 2,500 mm.

Montane temperate forests are found in the higher elevations, above 1,250 m, mainly within the wet zone. The height of the canopy varies from 8 to 12 m and the trees are of poor form, having dense spreading flat-topped crowns.

The submontane or mid-country tropical evergreen forest is a transitional vegetation type between the low country tropical evergreen forest and the montane temperate forest, and is found in the wet zone between 750 m and 1,250 m elevation. Most of these forests have been cleared for plantation crops and only a few remnants are found confined to mountain slopes.

The dominant type of natural vegetation found in the dry zone is the dry mixed evergreen forest, which covers about two thirds of the island (northern half and southeastern sectors). The mean annual rainfall is between 1,250 mm and 1,750 mm; in the east and central hilly areas a slightly higher rainfall is experienced. The trees are mainly microphyllous or mesophyllous and consist of both evergreen and deciduous species. The structure of the forest is relatively simple, with the deciduous species slightly taller than the evergreen species and with somewhat less than complete cover.

Tropical thorn forests are found in the drier coastal plain of the northwest and southeast areas of the island where the mean annual rainfall is less than 1,000 mm.

A *savannah* forest type is found on the eastern slopes of the central massif between elevations of 250 and 750 m in the rainshadow areas of the southwest monsoonal winds.

The grassland group is made up of: (1) the wet *patanas* of the up-country wet zone, (2) the dry *patanas* of the up-country intermediate zone, (3) the edaphic *villu* grasslands of the backswamps of major river systems in the low country dry zone, and (4) the edaphic-biotic *damana* grasslands of the eastern low country dry zone.

A vegetation map for the country was published by Gausen et al. (1965), which was based on a synthesis of the earlier vegetation maps of Koelmeyer (1957) and Holmes (1956). The zones or series delineated in this map are based on the concept of Potential Natural Vegetation. According to the paper of Gausen (1965), climate and soil have both been used in the delineation of the boundaries.

A few studies have been made in the past on the correlation between soil and vegetation. Joachim and Kandiah (1942) studied the reasons for the existence of *patana* grasslands and *kekilla* fernlands side by side with forests. Holmes (1951) studied the *grass, fern and savannah* lands and arrived at conclusions regarding their origin and development. Abeywickrema (1959) studied the natural vegetation in greater variety and extended his research to marine, salt marsh, mangrove, sandy shore, dune, fresh water, and marsh vegetation; he had also attempted a correlation with soils.

A more recent study by de Alwis and Eriyagama (1969) on soil-vegetation relationships in the low land dry zone could be considered a landmark publication in this field. As rightly observed by the authors "it would be incorrect to conclude that each type of vegetation exists on one great soil group only, or that each great soil group supports only one type of vegetation: numerous variations in micro-climate and biotic and historical factors preclude such a possibility." Somasiri and Panabokke (1968) have reported on the edaphic and biotic factors that govern the development of the *damana* grasslands of the Tamankaduwa area, based on observations they had made during the conduct of soil surveys of the area.

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CHAPTER 3

Soil Formation, Soil Profile, and Soil Identification

3.1 INTRODUCTION

It was only in the last century that a study of the soil as an independent science began to develop. Despite the rapid growth of geology, botany. and related natural sciences in Europe during the eighteenth and nineteenth centuries, comparatively little effort was devoted to a scientific study of the soil. While the scientists in western Europe were studying soils, mainly with the aim of obtaining higher crop yields, certain fundamental and revolutionary ideas on soil were emerging in Russia under the leadership of Dokuchaev, during the closing stages of the nineteenth century. It should be realized that Russia was a vast region over which there was a well-defined succession of climatic belts from south to north. Dokuchaev observed that each climatic belt or zone had a characteristic kind of soil. With further examination and study of the soil, he observed that a particular soil is made up of different layers or horizons, each kind of soil having its respective layers or horizons arranged in a particular manner. This observation of his was as important to the scientific study of soil as anatomy was to medicine.

The nature and sequence of the various zones of a soil from the ground surface to the parent rock material from which the soil developed is termed the soil profile. In the same way as different people can be identified by their features, a soil too can be recognized by its features, which are expressed in the nature and arrangement of the component soil horizons on the face of the soil profile. With the assistance of other outstanding scientists such as Sibirtsev and Glinka, the Dokuchaev School of Soil Science eventually recognized that the five principal factors of soil formation are:

- Climate
- Parent material
- Topography or relief
- Vegetation and living organisms
- Time or age of the landscape

Today, these are referred to as the five genetic soil-forming factors.

In our own country, it is not so difficult to observe the relative influence of each of the above factors in some degree or the other. For instance, the soils that are found in the climate of the wet zone of Sri Lanka are quite different to those found in the climate of the dry zone where, within the same climate, soils that developed on the Bintenne gneisses are different from those that developed on the Wanni gneisses. The influence of topography is quite evident in the gently undulating landscape of the dry zone where the soil on the high aspect of the land is reddish brown in colour while the soil on the adjacent lower aspect of the land is grayish brown in colour. The influence of vegetation can be seen in areas of sharply contrasting vegetation. For example, significant differences can be observed in two soils that are just hundred yards of each other, where the vegetation of one is tall forest and the other is grassland. One of the most important points to bear in mind about the influence of time is that soils develop very slowly; the age of a soil could be several thousand years or even close to a million years. Soils also undergo change and become older just as people do. Like the stages of youth, maturity, and old age in the life of a human being, we can recognize young soils, mature soils, and old soils in soil development. The soils in the hilly regions are usually young because the landscape itself is frequently rejuvenated by erosion. Old soils are usually found on flat or gently undulating landscapes that have remained geologically stable for thousands of years.

3.2 WEATHERING

Weathering down of rock to form the parent material for soils is largely a destructive process. On the other hand, the development of the soil profile on the weathered products of rock is largely a building-up process. However, both these processes follow each other so closely that it is difficult to say where one ends and the other begins. It is like the overlapping fibres in a piece of string where one could hardly tell where one fibre begins and the other ends.

Two types of weathering are recognized, physical weathering and chemical weathering. In this country, physical weathering is mainly caused by the alternate heating up of the rock by the sun and sudden cooling by rain. You may have often observed portions of a rock surface peeling off very much like the skin of a fruit. This is chiefly a result of physical weathering.

Chemical weathering is a more complex process that is more intense than physical weathering, especially under tropical conditions. Rocks as you know are made up of a number of different kinds of minerals. During chemical weathering, these minerals are decomposed and new substances are formed. Water and the carbon dioxide dissolved in the water are the chief agents of chemical weathering. Rock minerals themselves can be divided into non-weatherable minerals and weatherable minerals. Quartz is the most common non-weatherable mineral that is present in our rocks. It is very resistant to chemical weathering and remains only slightly altered when most of the other rock minerals have undergone some degree of chemical change. The more common weatherable minerals present in our rocks are feldspars, micas, and ferromagnesian minerals such as horneblende and biotite. These are easily subject to chemical weathering under the climatic conditions prevailing in Sri Lanka.

These weathered products of rock are the parent materials on which a soil begins to develop, and such weathered rock products are termed the soil parent material. It is useful to distinguish parent material from parent rock. The latter is the original unweathered rock, whereas the parent material is the product of the weathering processes and is the material on which development of a soil profile occurs.

3.3 PROFILE DEVELOPMENT

The top meter or more of the weathered material is usually much changed by the action of plant roots, fungi, bacteria, and soil fauna. Dead plant material is rotted by fungi and bacteria or consumed by soil fauna, particularly termites in the tropics. In these processes much of the original plant material is converted into carbon dioxide and water, but a portion is changed into the insoluble organic substances that make up the organic matter of the soil. These processes take place chiefly on the surface and in the top few centimeters so that most of the organic matter is found in this upper layer.

The weathered material is also modified by rainwater. Where the rainfall is high, there is usually sufficient percolation to carry away the soluble products of weathering and plant decomposition into the rivers. As a result the soil tends to become acid. Where the rainfall is moderate, the soils tend to become neutral. When, however, the rainfall is very low, the soluble products tend to accumulate and the soils tend to become alkaline.

All these changes chiefly affect the top meter or more of the weathered material and produce a soil profile consisting of successive horizons one below the other, and all roughly parallel to the land surface.

Since profile development is restricted to the surface while weathering is not, the latter has, over much of tropical Sri Lanka, gone deeper than profile development and is currently taking place much below the depth of the soil. This weathering front lies at a depth of over 6 m below ground level in the wet zone, and at a depth of about 3 m in the dry zone.

It is also useful to distinguish between geochemical weathering that takes place within the weathering front, and pedochemical weathering, which is the breaking down of minerals within the soil profile.

3.4 THE SOIL PROFILE

The main characteristics of a soil profile are shown in figure 8.

The uppermost horizon, which is the topsoil, is referred to as the A horizon. The organic matter is concentrated in this horizon and it is therefore darker in colour than the rest of the profile. It is also called the eluvial horizon because material has been removed from this horizon by leaching or eluviation. Below the A horizon is the subsoil or B horizon. It is also called the illuvial horizon because most of the material removed from the A horizon by leaching has been deposited in this B horizon. The A horizon is a horizon of impoverishment, while the B horizon is a horizon of enrichment. Where the B horizon is enriched with clay that moved down from the A horizon, it is referred to as a textured B or a Bt horizon. In modern terminology it is called an argillic or argic horizon. Below the B horizon is the C horizon. These horizons, A,B, and C, together constitute the soil profile. Each of these horizons could be further subdivided into subhorizons such as A1, A2, A3, and B1, B2, B3, etc. by a trained and experienced soil surveyor. These horizons and subhorizons that are formed by the normal soil-forming processes are referred to as the genetic soil horizons.

In the field, the soil scientist studies the main features of the soil profile on a freshly cut face of a profile. He notes the nature and arrangement of all the component horizons and subhorizons. He notes the colour, texture, structure, and consistence of the soil in each of these horizons.

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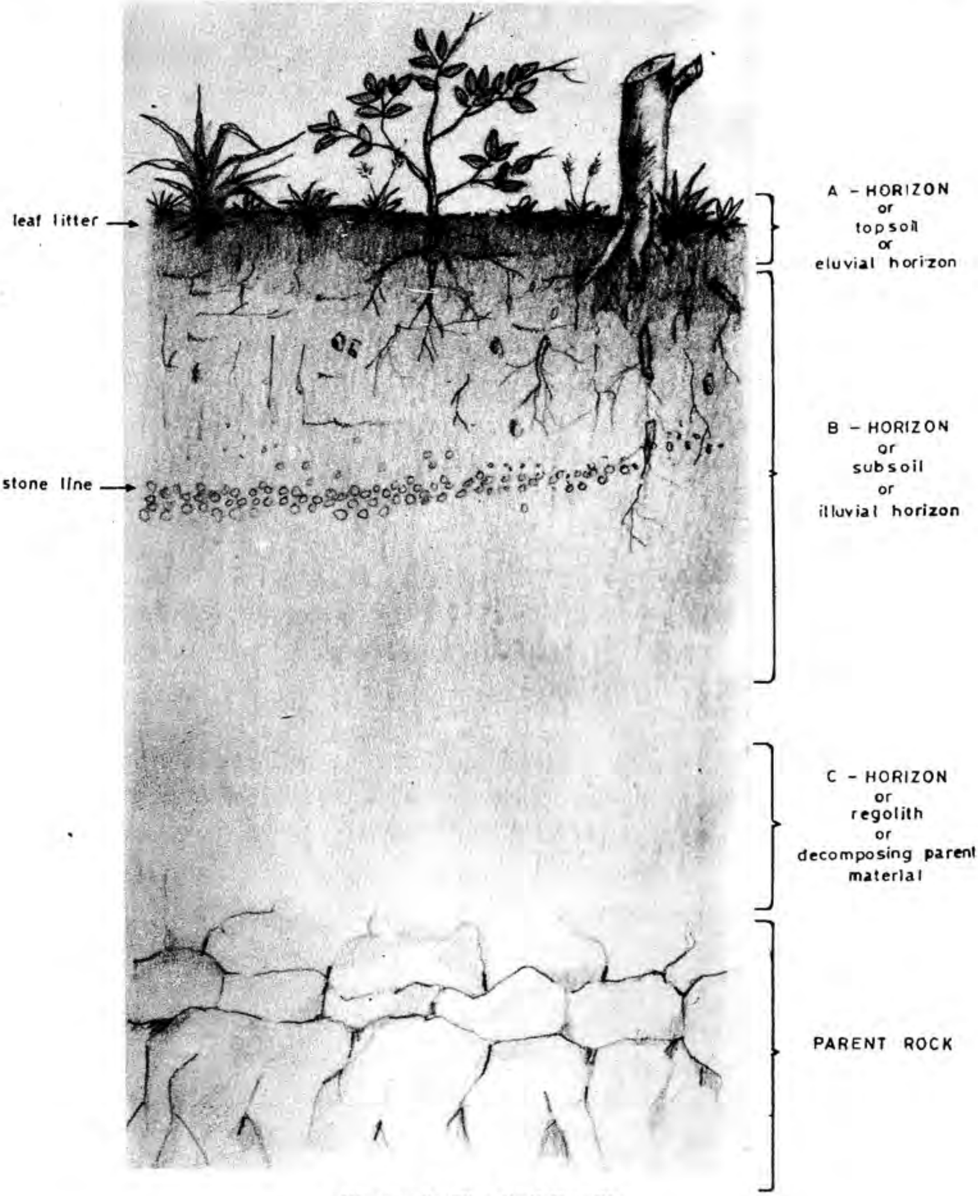

Figure 8: The Soil Profile.

It is not always easy to distinguish the respective horizons of a soil profile in the field because of a number of complicating factors. In the tropics especially, the change from one horizon to the other is not as clear and distinct as in the temperate regions of the world. In spite of these complicating factors that are encountered in tropical countries, considerable headway has been made in the field techniques of soil study.

Once the nature, arrangement, and properties of the individual soil horizons of the soil profile have been confirmed, it is then possible to give a specific name to the soil.

3.5 SOIL IDENTIFICATION

The main points to notice in a soil profile are, first, the differentiation of the face of the profile into its respective horizons, and, second, the more important soil characteristics of each horizon. These soil characteristics are colour, texture, structure, consistence, and presence of mottles. One should also note the presence of mottling or staining that occurs at a particular depth of the soil profile, and the presence of quartz gravel, ironstone, gravelly concretions, and calcium carbonate concretions within the soil profile.

Most soil profiles have the three master horizons, A horizon, B horizon, and C horizon. On badly managed soils and soils that occur on very steep land, it is usually observed that the complete A horizon and even a good portion of the B horizon have been eroded away.

In the temperate regions, the change from one horizon to the other can be quite clearly observed on the face of the freshly exposed profile. In the tropical regions, on the other hand, this change or transition from one horizon to the other is not so distinct, and it therefore demands a certain amount of practice before one could get accustomed to observing the profile differentiations.

The thickness of the individual soil horizons may vary from a few centimeters to a meter or more. The A horizon of most of the soils in this country is less than 30 cm in thickness. The B horizon is usually a meter or more in thickness; in wet humid regions, the thickness of the B horizon is often in excess of 2 m. *Guidelines for soil description are given in the FAO Publication* (1967).

With the aid of the general descriptions that are provided in the next chapter in respect of each of the great soil groups, together with references to the soil map that is annexed at the end of this book, the reader should find no difficulty in identifying the more important soils of Sri Lanka.

Soil profiles can be studied on cut surfaces of soil like those seen in trenches, freshly-cut wells, burrow pits, excavation sites, foundation trenches, etc. It is best to clean the face of the profile that is to be studied by shaving off a layer of soil about 5 cm thick, with the aid of a spade.

3.6 GREAT SOIL GROUPS AND SOIL SERIES

All soils that belong to a particular great soil group will have a similar sequence and arrangement of master horizons and subhorizons within the soil profile. It is, however, not necessary for the individual master horizons and subhorizons to be of the same thickness in all the soils that belong to the same great soil group; considerable variation in the thickness of the individual master horizons and subhorizons that make up the profile of a particular soil is permitted. The main soil characteristics such as colour, structure, consistence, soil reaction, and exchange complex of the master horizons will be very nearly similar in all soil profiles that belong to a certain great soil group; a certain degree of variation in texture is permitted within a great soil group.

As a convenient practical measure, an intermediate category of a subgroup has been adopted in this country in order to classify soils that differ from the typical great soil group in one important feature.

Soil Series

Soils that developed from the same parent material under similar conditions and have the same sequence of master horizons and subhorizons within the profile belong to the same *soil series*. The soil series is the most convenient unit for certain kinds of soil surveys. The soil series name is usually derived from the place where the soil was first identified during the soil survey. We thus have soil series names such as the Alutwewa series, Ranorewa series, Walawe series, Maho series, Wilpattu series, etc. More than 250 soil series have been recognized up to now in Sri Lanka.

3.7 SOIL MINERALOGY

For ease of better understanding and discussion, it seems convenient to separate soil minerals into two broad groups: (1) skeletal minerals, which mostly consist of sand and silt size fractions, and (2) clay minerals, which constitute the main portion of the clay fraction of most soils. Both groups of soil minerals can be arranged in an order of their stability or, conversely, their weatherability, which can be used to broadly assess the degree of weathering of a given soil as well as the native nutrient reserves of soils.

Of the skeletal minerals, the more easily weatherable minerals are olivine, pyroxene, and amphibole and the least easily weatherable minerals are quartz and muscovite, with biotite and feldspars occupying an intermediate position. The amount of weatherable minerals that could be observed in the different horizons of a soil profile generally reflect the age or the degree of weathering of the soils as well as the stage of advancement of profile development. Techniques and criteria used to identify mineral grains and their importance in soil mineralogy have been prepared by Cady (1965).

The clay minerals are made up of both crystalline layers of aluminosilicate clays as well as hydrous iron oxides and gibbsites that occur in more highly weathered soils. A useful and convenient model for weatherability of clay size minerals is the weathering sequence proposed by Jackson (1968). Smectites (montmorillonite and relatives) are found in less-weathered soils, while gibbsite is found in highly weathered soils. Clay minerals such as vermiculite, illite, and kaolinite occupy an intermediate position with kaolinite representing the more advanced stage of weathering. The type of clay minerals present in a soil generally reflects the intensity of weathering factors to which the soil has been submitted. One could also infer the physical qualities and cation exchange characteristics of soils from clay mineral data.

Studies on the clay mineralogy of Sri Lankan soils have been reported by Panabokke (1958), Kawaguchi and Kyuma (1967), Herath and Grimshaw (1971), Yapa (1988), and Mapa (1992). Studies on both clay minerals and skeletal minerals have been reported by Kalpage et al. (1963), de Alwis and Pluth (1976), Handawela (1983), and Tampoe (1989).

3.8 SOIL MAPPING AND SOIL MAPS

When we map soils, in effect, we map soil profiles. The soil map is a map of soil profiles. Soil mapping is a fairly specialized task that requires considerable skill, judgment, and experience. You may have observed a soil surveyor walking across a field with a soil auger or spade in his hand, and a base map, which is an aerial photograph held in front of him. Every now and again he stops to bore or dig a pit in the soil. He studies the colour, texture, structure, and other important features of the soil at different depths and notes his observations on standard soil description sheets. He examines a pair of aerial photographs under the stereoscope and marks sketches and boundaries on these photographs. He is always alert and preoccupied as if he were searching for some vital clue.

The techniques of soil mapping that are used in the field vary from one country to another. Survey and mapping of soils in temperate countries are comparatively easier than in tropical countries. The soil distribution patterns in temperate countries are fairly clear-cut and are easily recognizable both in the field as well as on aerial photographs. In the tropical regions, on the other hand, the patterns are very complex and are not easily recognizable on aerial photographs; a considerable amount of field control and field studies in conjunction with study of aerial photographs are required to recognize them. Despite such difficulties, it is now possible to carry out accurate soil mapping in the tropical regions once the basic mapping legends have been worked out by competent soil scientists. It has taken several years of basic scientific investigations in Sri Lanka to establish proper mapping legends for the different regions of the country. It should, however, be noted that no reliable soil map could be made solely by the interpretation of aerial photographs.

It is necessary for the reader to understand the significance of certain terms such as soil association, soil catena, soil complex, land type, etc., which are commonly used in the legends that accompany a standard soil map. These terms refer to the mapping units that are employed to depict the distribution patterns of the different kinds of soil, which occur in the survey region. The foregoing terms are strictly mapping units and should not be confused with soil classification units.

Soil association is the most common mapping unit that is employed in this country. When two or more kinds of soil are found in a certain type of landscape unit in such a manner whereby each kind of soil always occupies a definite relative position in this landscape unit, one could then refer to this as a soil association. For example, in most of the undulating landscape units of the dry zone, the reddish brown earths occupy the upper aspect of the relief, the yellowish brown earths occupy the mid-aspect of the relief, and the low humic gley soils occupy the lower aspect of the relief, as shown in figure 9. This can therefore be described as an association of reddish brown earths, yellowish brown earths, and low humic gley soils. It is also referred to as a soil catena.

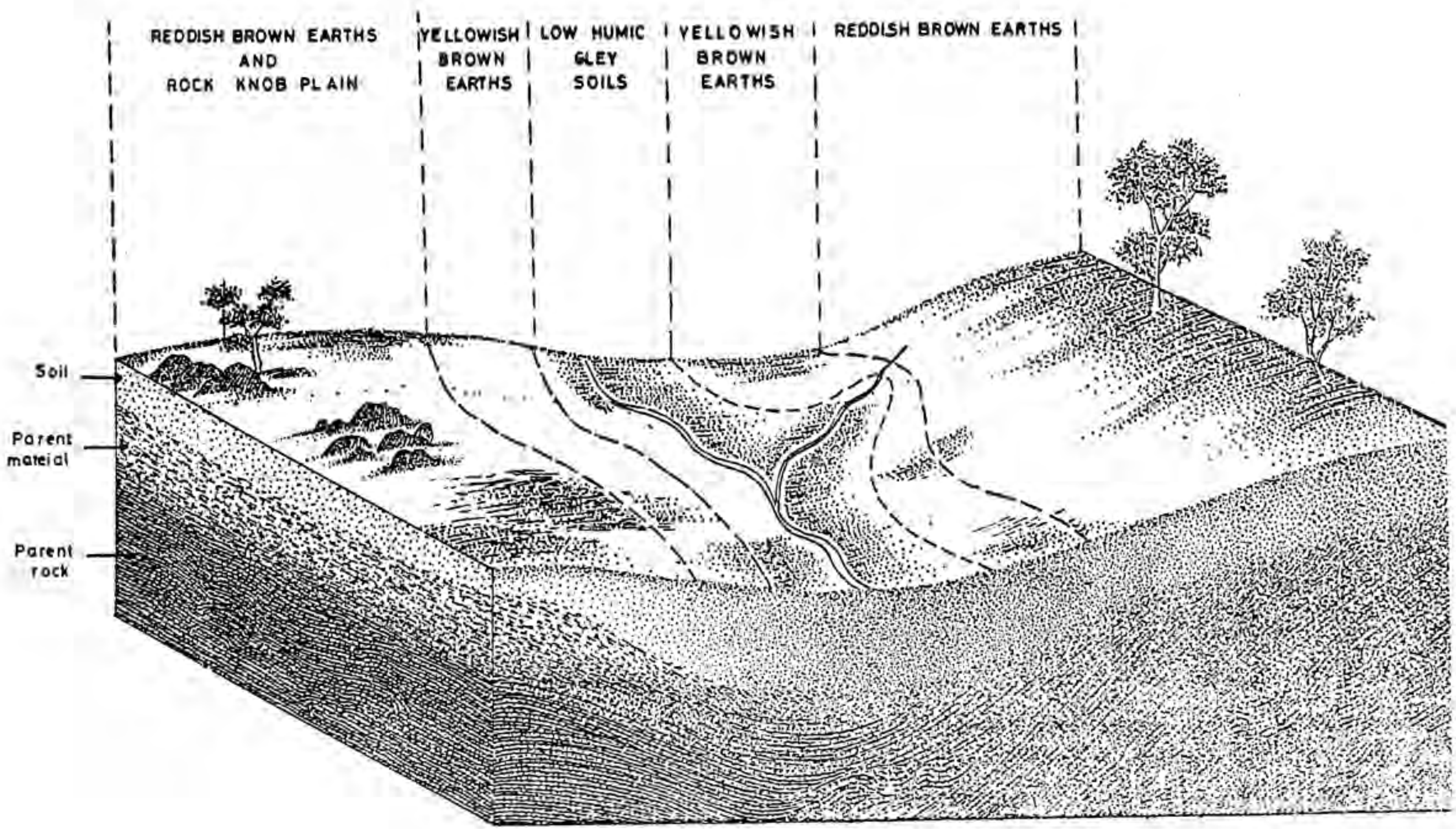

Figure 9: Soil Association or Soil Catena.

In a soil complex, it is difficult to observe such a definite pattern in the relative positions occupied by the different kinds of soil in any particular landscape unit. However, when it is known that two or more different kinds of soil do occur in a very complex pattern in a certain type of landscape, these can be shown as a soil complex on the soil map.

Certain types of landscapes, which are easily recognized and which are usually of fairly low agricultural potential, can be depicted as land types on a soil map. These include erosional remnants, rock knobs, eroded land, rocky land, dunes, tidal marshes, etc.

Terms such as reconnaissance, detailed reconnaissance, and semi-detailed reconnaissance that were formerly used to describe the soil survey intensity have been replaced by new terminology as shown in table 2.

TABLE 2: New Terminology in Soil Survey Intensity

Former terminology	Present terminology	Range of scale	Kind of mapping unit
Reconnaissance	Low Intensity	1:100,000 to 1:250,000	Association of great soil groups
Detailed Reconnaissance	Medium Intensity	1:25,000 to 1:100,000	Associations of soil series; physiographic units, enclosing soil series
Semi-detailed	High intensity	1:10,000 to 1:25,000	Phases of soil series; soil series

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CHAPTER 4

The Great Soil Groups of Sri Lanka, their Environmental Setting, Main Characteristics, and Taxonomic Placement

This chapter attempts to generalize a large body of data gathered over more than three decades from the National Soil Survey of Sri Lanka and associated field studies. These studies were carried out by the soil survey staff of the Land Use Divisions of the Irrigation and Agriculture agencies. It is not proposed to describe any of the great soil groups in morphological detail, but rather to deal with their relationships to environmental factors. This treatment is used to present the relationships of the soils to various climates, various forms of topography, parent materials, and nature of soil forming processes. The soil-landscape relationships are discussed later, in the next chapter.

There is growing interest in and recognition of the importance of the mineralogy of clay minerals, which gives a general idea of the stage of advancement of pedogenic weathering in a soil. Therefore, an attempt has been made to bring together, for each great soil group, the available information from different sources.

The placement of the respective great soil groups at the Great Group level according to Soil Taxonomy (1975) is given towards the end of the description for each great soil group.

The recent (1991) FAO World Soil Resources Map (WSR) fulfills two requirements. It provides a synthesis of world soils that facilitates an understanding of how soils relate to climates, vegetation, and the geography of continents. It also encourages the use of internationally recognized names for soils rather than inexact confusing names such as laterite, meadow soils, desert soils, etc. The WSR map has 28 major soil groupings (not taxonomic groups) subdivided at the second level to 153 soil units (also not taxonomic). The equivalent of each of the great soil groups of this country at both the major grouping level and the WSR map unit level is given at the end of each description. This would help the general reader to compare the soils of Sri Lanka in a wider global setting. Further aspects of this will be elaborated in chapter 6.

For more detailed information on the diagnostic characteristics of the master soil horizons and the morphology of the great soil groups the reader is referred to the following two publications:

1. *Soils of Ceylon — A New Approach to the Identification and Classification of the More Important Soil Groups of Ceylon* by F.R. Moormann and C.R. Panabokke (1961). Tropical Agriculturist Vol 117, 1961.

2. *Handbook of the Soils of Sri Lanka* by K.A. de Alwis and C.R. Panabokke (1972). Journal of the Soil Science Society of Ceylon Volume 2.

Over the last three decades, the soils of the dry zone have been studied and mapped at a more systematic level than those of the wet zone. As a result, the definition of the central concept for dry zone soils is sharper than that for wet zone soils. Even within the dry zone, some great soil groups have been studied and characterized in more detail than others. This will be reflected in the nature of the descriptions and characterizations that follow in respect of the individual great soil groups.

The great soil groups discussed in this chapter are limited to those that are shown in the General Soil Map of Sri Lanka attached at the end of this publication.

SOILS OF THE DRY ZONE AND SEMI-DRY INTERMEDIATE ZONE

4.1	Reddish Brown Earths
4.2	Low Humic Gley Soils
4.3	Noncalcic Brown Soils
4.4	Red-Yellow Latosols
4.5	Alluvial Soils
4.6	Solodized Solonetz
4.7	Regosols
4.8	Soils on Old Alluvium
4.9	Grumusols
4.10	Immature Brown Loams (dry zone subgroup)

4.1 REDDISH BROWN EARTHS

This is the most widespread great soil group in Sri Lanka and it occupies the largest area compared to all other soils. Soils belonging to this great soil group are mainly developed on residuum and colluvium derived from intermediate and basic Precambrian rocks that have a sufficient content of ferromagnesian minerals. Very often the upper part of the profile is developed on semi-recent colluvial materials, and the lower part on much older, frequently somewhat transported, residual materials. The two parts are often separated by a stone line or erosion pavement. Illuviation of clay or lixiviation appears to be a dominant process in the development of the reddish brown earths as evinced by the occurrence of cutans on ped surfaces and on pore walls.

The reddish brown earths are mainly confined to the dry zone and they occur in a catenary sequence with the other drainage members on the undulating mantled plain of the lower planation surfaces of the dry zone. They occupy the crests and the well-drained upper- and mid-slopes of the undulating landscape. A small extent is found in the transitional planation surface of the intermediate zone where they occur on rolling to hilly terrain.

The colour of the surface soil is characteristically reddish brown when dry, changing to dark reddish brown when moist. The colour of the subsoil is distinctively redder than the surface soil. The normal uneroded soil profile consists of sandy loam to a sandy clay loam surface horizon underlain by a sandy clay loam to sandy clay subsoil argic horizon. Most commonly, a subsoil horizon with a high proportion of quartz gravel is present. The depth to this gravel horizon is quite variable, and the gravel itself is made up of subangular quartz gravel, angular feldspar gravel, and iron-manganese nodules in different proportion. The profile sequence is usually A1,B1t,B2t,B3t,C.

Plate 1 (frontispiece) shows a profile of a reddish brown earth in the Anuradhapura District.

The surface soil structure is weak to moderate, coarse, subangular blocky. The soils are extremely hard when dry, friable to firm when moist, and sticky when wet. The base saturation in the subsoil is in the range 60-80 percent; and soil reaction slightly acid to neutral. The soil moisture relationships are characterized by a low water-holding capacity with a rapid release of soil moisture at tensions lower than one atmosphere. The physical properties of the reddish brown earths have been studied and reported in considerable detail by Joshua (1988).

According to the studies of Panabokke (1959), Kalpage (1963), and Mapa (1992), the clay minerals of these soils are mainly kaolinite, followed by illite and some smectite occurring in the lower B horizon and upper C horizon. Kawaguchi and Kyuma (1967) and Handawela (1983) have reported the presence of significant quantities of smectite in the upper horizons of the hydromorphic associates of the reddish brown earths, and the presence of 25 to 30 percent illite in the surface horizons. The presence of weatherable minerals in the sand fraction (Handawela 1983) indicates an intermediate stage of weathering of these soils.

The type location for this great soil group is undoubtedly the dry zone of Sri Lanka. Its closest analogues are found in similar climates of east and west Africa, especially where the soils are derived from the basement complex of rocks. Their equivalents in Asia have been described as Red Mediterranean soils by Dudal and Moormann (1964) and Red Brown Earths in Thailand by Moormann (1972).

The taxonomic placement of the modal member of the reddish brown earths according to Soil Taxonomy (1975) is:

Order - *Alfisols*
Suborder - *Ustalfs* (Ustic denoting dryness)
Great Group - *Rhodustalfs, Haplustalfs*

In the World Soil Resources (WSR) Map the placement is:

Major grouping - *Luvisols* (LV) and *Lixisols* (LX)
World Soil Map Unit - *Chromic Luvisols* (LVx)

The natural vegetation most commonly found is dry mixed evergreen forest, most of which is secondary; the original forest has been destroyed by shifting cultivation. The dry faciation or standard, is by far the most important and widespread in this soil region. In the drier parts of the Mannar and Hambantota districts, the very dry or semiarid faciation consists of thorny scrub jungle with stunted emergents. Some aspects of the paleo-climate of this soil region and the prehistoric settlement sites have been described by Deraniyagala (1992).

4.2 LOW HUMIC GLEY SOILS

Next to the reddish brown earths, low humic gley soils are the most extensive great soil group in Sri Lanka. By virtue of their positions in the landscape, these are essentially hydromorphic soils developed on the local colluvium that has built up during long periods of landscape formation at the footslopes of the undulating landscape. The dominant factor that governs the expression of these soils is the periodically high groundwater level; this may be true groundwater or a water table that develops on an impermeable stratum during the rainy season.

The low humic gley soils are found throughout the lowlands of Sri Lanka, usually in the low lying ground above alluvial or colluvial parent materials. In the dry and intermediate zones of the country, they occur as the lower members of the drainage catena in association with either the reddish brown earths or the noncalcic brown soils. They are not found in the hilly terrains or in the regions of mountainous relief.

These soils are characterized by wetness or gleying throughout the profile, or gleying immediately below the surface horizon. They also have a textural B or argic horizon, which frequently shows conspicuous mottling. The colour of the surface soil is dark greyish brown to dark brown, and that of the subsoil is greyish to yellowish brown with distinct mottles and gleying. The normal profile consists of a sandy loam to sandy clay loam surface horizon underlain by a sandy clay to clay subsoil horizon. Calcium carbonate concretions, sometimes referred to as kankar, are found in the lower depths of the profile in the drier environments. The depths of occurrence of these carbonate concretions correlate well with the degree of leaching or the dryness of the present climate.

In a well-developed undisturbed profile, the horizon sequence is A1, A2, Btg, C. According to the soil surveys carried out so far, two broad categories of low humic gley soils are found in the dry zone. The first and more widespread category consists of deep sandy clay loams underlain by sandy clays and with abundant calcium carbonate concretions below 1 meter depth. The second category is usually of a much lighter texture and with very little or no carbonate concretions. The former is associated with the reddish brown earths, and the latter with the noncalcic brown soils.

The surface soil structure is subangular blocky to massive. Structural forms are more visible in the subsoils when the profile dries out to some depth during the dry season. These soils are extremely hard when dry and sticky when wet. The base saturation in the subsoil is in the range of 90-100 percent and free carbonates are present at varying depths of the subsoil; soil reaction is thus moderately alkaline. The water holding capacity of the subsoil is fairly good because of the presence of smectite clay minerals.

According to Panabokke (1959), Kawaguchi and Kyuma (1967), and Mapa (1992), the dominant clay minerals are both kaolinite and smectite, with a minor presence of mica, chlorite and vermiculite. Yapa (1988) reports a similar assemblage of clay minerals.

In Sri Lanka, the low humic gley soils are found mainly in the broader inland valley systems of the dry and intermediate zones. In contrast, in the rest of Asia they commonly occur in large surfaces on the major stream terraces.

The taxonomic placement of the modal members of the low humic gley soils is:

Order - *Alfisols*
Suborder - *Aqualfs* (aquic or wet)
Great group - *Tropaqualfs*

In the World Soil Resources (WSR) map the placement is:

Major grouping - *Gleysols* (GL)
World Soil Map Unit - *Eutric Gleysols* (GLe)

The composition of the natural vegetation on the low humic gley soils is not much different from that of the associated reddish brown earths or noncalcic brown soils. But, the stands may be poorer in some instances due to waterlogging at periods, or richer in other instances due to the more favourable moisture conditions.

4.3 NONCALCIC BROWN SOILS

The noncalcic brown soils are a more complex group of soils because the definition of their central concept has to be updated from time to time with the availability of new information. Soils belonging to this great soil group are almost exclusively developed on either colluvium or alluvium derived from acid rocks of the Vijayan series that have a low content of ferromagnesian minerals.

Where the parent material is well supplied with ferromagnesian minerals, these soils are replaced by reddish brown earths. Weakly developed noncalcic brown soils are observed on quartzitic transported materials derived from acid rocks as well as on terrace deposits of old sandy alluvium. The transitional soils of the intermediate zone around Moneragala are found on somewhat less acid parent material. The well-developed noncalcic brown soils developed on acid to intermediate parent materials, as in the Maho catena, are distinguishable from the reddish brown earths mostly by their colours.

The noncalcic brown soils occur mainly in the lower planation surfaces of the dry zone and parts of the intermediate zone. The coarser textured noncalcic brown soils are generally associated with the middle and upper terraces of prior river systems. They occur in association with the other drainage members in the lower planation surfaces and also in some parts of the intermediate planation surface. They also occur in a complex pattern with other soils on the irregular and complex landscapes of the highly contorted and folded Vijayan rocks. Their relationship to the landscape is therefore more complex than that of the reddish brown earths, which show a very clear catenary relationship with the landscape.

The colour of the surface soil is dark brown to dark greyish brown, and that of the subsoil is yellowish red to yellowish brown. The normal profile consists of a sandy loam surface horizon underlain by a sandy loam to sandy clay loam subsoil horizon. The profile sequence is A1,A2,B (1,2,3) t, C. The C horizon consists of decomposing acid gneisses that are of a very light colour because of the low content of ferromagnesian minerals. The material of this C horizon is very friable and has a sugar like appearance when crushed in the hand.

The surface soil structure is weak, subangular blocky. These soils are slightly hard when dry and slightly sticky when wet. The base saturation in the subsoil is between 50 and 70 percent; soil reaction is medium acid. The water-holding capacity is low to very low. According to Yapa (1988) and Kawaguchi and Kyuma (1967), kaolinite is the dominant clay mineral, but a significant content of illite is also recorded.

The coarser textured noncalcic brown soils are best expressed in the inland parts of the Batticaloa and Ampara districts, and the moderately coarse textured soils around Moneragala and around Maho in the Kurunegala District. In the Tamankaduwa *damana* region and its immediate surroundings, they occur in a more complex pattern with other soils such as soils on old alluvium and solodized solonetz. Considerable extents of noncalcic brown soils are found in the comparatively drier tropical regions of Asia where the parent materials are rich in quartz.

The taxonomic placement of the modal member of the noncalcic brown soils is:

Order - *Alfisols*
Suborder - *Ustalfs*
Great Group - *Haplustalfs*

In the World Soil Resources (WSR) Map the placement is:

Major Grouping - *Lixisols* (LX)
World Soil Map Unit - *Haplic Lixisols* (LXh)

The natural vegetation is dry mixed evergreen forest. But the growth is generally poorer than that supported by reddish brown earths, although the species composition is more or less the same. In some areas, the forest grades into parklands where the soils are not significantly different from those under forest.

4.4 RED-YELLOW LATOSOLS

Both great soil groups of red latosols and yellow latosols together with the subgroup of calcic red latosols are considered under this heading. The red-yellow latosols occupy a very distinctive landscape position in the coastal region of northwestern, northern, and northeastern Sri Lanka as could be seen in the soil map of the island. The inner boundary of these soils corresponds to an old shore line, perhaps of the early Quaternary. These soils are thus located on an old depositional surface sometimes referred to as an upwarped Pleistocene coastal plain. They are developed on weathered materials derived from the adjacent eroded land surfaces. The near-shore or beach-dune-ridge deposits that constitute this landscape are made up of this pre-weathered material. This landscape has remained stable for a very long period because of the very high permeability of the soils and thus the absence of erosion even under high rainfall intensities. This is in contrast to the adjacent planation surface with reddish brown earths that is subject to geological sheet erosion at the commencement of each rainy season when high intensity convectional rains are experienced. This is evident in the relative base to summit levels of the two landscapes.

One of the most striking characteristics of the red latosols is their great depth and extreme uniformity throughout their depth and, therefore, lack of clear horizon differentiation. Gravel of any type is absent in the profile, but is encountered at lower depths of the landscape as basal ferruginous gravels, as described by Cooray (1984). They occur in an arcuate belt generally about 20 km wide, with the outer boundary being the present shoreline and the inner landward side boundary corresponding to a very approximate 30 meter elevation contour. A few isolated patches of red latosol also occur on the south and southeastern coast. The red latosols are found on the high aspect of the relief, while the yellow latosols are found on the lower aspects of the relief. The calcic red latosols occur mainly in the Jaffna peninsula. Deraniyagala (1992) refers to the basal gravels together with the overlying latosols as the Iranamadu Formation (IFm) in contrast to Cooray's (1984) more restrictive definition of the red-earth formation.

The colour of the surface soils of the red latosols is dark reddish brown, and that of the subsoil is dark red. The profile consists of a loamy sand or sandy loam surface A1 horizon, underlain by a slightly heavier textural B horizon, which may continue unchanged for more than 12 m. The horizon sequence is A1,B,C.

The surface soil structure is weak subangular blocky to structureless, and of a loose to friable consistence when dry, and very friable when moist. The base saturation in the subsoil is in the range 20-60 percent; and soil reaction is medium acid. The physical properties of these soils are generally good. They have very rapid infiltration, a good workability but a very low water-holding capacity.

The yellow latosols differ from the red latosols mainly in respect of colour, which ranges from yellowish brown to yellowish red, and also in drainage, being moderately well to imperfectly drained. The calcic red latosols are shallow red latosols developed on transported material that overlies Miocene limestone, and most of the soils have ruptic profiles. Deep pockets of soil are found in the weathered and dissolved limestone crevices. Soils of this subgroup have a high base saturation, and pH values between 7 and 8.

The mineralogy and weathering of the red latosols of Sri Lanka have been studied in greater detail than any other soil group in this country by de Alwis and Pluth (1976). The dominant clay mineral is well-crystallized kaolinite with a smaller presence of mica and haematite. Weatherable minerals are almost absent. Pedological weathering has taken place under climatic conditions similar to the present, but over a very long period.

Although in Sri Lanka these soils are confined to the old depositional surfaces of pre-weathered materials in a dry climate, Dudal and Moormann (1964) report the occurrence of red yellow latosols in several southeast Asian countries under a wide range of climates and parent materials. These are the dominant soils of eastern Malagaysay (Madagascar) central Africa and Brazilian South America.

The taxonomic placement of the modal members of the red yellow latosols is:

Order - *Oxisols*
Suborder - *Ustox*
Great group - *Haplustox*

In the World Soil Resources (WSR) map the placement is:

Major grouping - *Ferralsols* (FR)
World Soil Map Unit - *Rhodic Ferrasols* (FRr) - red latosols
Xanthic Ferrasols (FRx) - yellow latosols

de Alwis and Eriyagama (1969) observe that some of the richest dry zone forests occur on the red-yellow latosols of the Oddushuddan-Mullaitvu region where the mean annual rainfall is around 1,500 mm. Even in the drier areas of the northwest latosol region, the forest growth is better than that on the reddish brown earths, and strikingly superior to the forest on the heavier textured soils. Aspects of the paleo-climate of this soil region and prehistoric settlements within the latosols have been described and discussed by Deraniyagala (1992).

4.5 ALLUVIAL SOILS

In this section, alluvial soils are mainly restricted to the soils that have formed on alluvium deposited on more or less flat flood plains as well as in valley depressions. It excludes most of the soils found on slope colluvium. In the soil map of Sri Lanka, the soil unit number 10 is denoted as alluvial soils of variable texture and drainage. Because of the great variation in texture and drainage of these soils, only a generalized description can be given here.

The materials from which the alluvial soils of the dry zone have been derived vary considerably, both in composition and in texture. In the larger floodplains such as those in the Mahaweli and in the Malwathu-Aruvi, this material is mainly fine textured or clayey, sometimes coarser textured. In the smaller floodplains and valleys of the interior, medium- textured sediments are more common. Within a single valley, texture varies according to a physiographic position. The coarser material is deposited on levees of rivers, and the finer textured material in backswamps and valley basins. The texture of the sediments varies further with the source of the transported material and with the regime of the rivers. The composition and mineralogy of the alluvial soils, especially in the secondary valleys, are greatly influenced by the kind of dominant soils and parent materials in the catchment areas. In the wider floodplains, the influence of the soils distributed in the catchment area is much less evident.

Three broad categories of alluvial soils can be recognized within the dry zone. The first category consists of alluvial soils that are found on the high banks of rivers and major streams. The second category consists of alluvial soils of the floodplains. The soil map of Sri Lanka essentially shows these two categories. Clayey alluvial soils of the third category are more scattered, and they occur in depressions of the landscapes and in sites of slack water deposits.

The pedological horizons are restricted to A1 or Ap and C or Cg. The characteristics of the A horizon vary mainly with regard to drainage and age of deposition. The A horizon of the better-drained alluvial soils is weak and may even be lacking any recent sediments. In the bottom lands with permanent high ground water, organic material accumulates and the A horizons are well developed. A feature of some alluvial soils is the presence of distinct layers with different textures not related to soil-forming processes, but related to the depositional history.

Drainage conditions and hence morphologies of the alluvial soils differ greatly. The poorly drained alluvial soils show a predominance of greyish colours with distinct mottling throughout the profile. Better drained soils are usually brownish or yellowish brown throughout, or with mottling starting at medium depth.

Soil reaction of the alluvial soils of the dry zone is slightly acid to slightly alkaline. Base saturation in the subsoil is between 60 and 90 percent. Available data on clay mineralogy by Herath (1985) and Kawaguchi and Kyuma (1967) show the dominant clay minerals as kaolinite together with some smectite, illite, and mica.

The taxonomic placement of the more recognized alluvial soils is:

Order - *Entisols*
Suborder - *Aquents and Fluvents*
Great Group - *Tropaquents*, *Ustifluvents* and *Tropofluvents*

In the World Soil Resources (WSR) Map the placement is:

Major Grouping - *Fluvisols* (FL)
World Soil Map Unit - *Eutric Fluvisols* (FLe)

As reported by de Alwis and Eriyagama (1969), *"the best dry zone vegetation occurs on these soils. Paradoxically some of the worst vegetation also exists on alluvial soils where a high water table or a very clayey texture impedes aeration. In general, tall trees with the other mesophytic species of the dry zone are found on these soils."*

4.6 SOLODIZED SOLONETZ

Soils of this great soil group are found on three different kinds of landscape positions:

- Marine deposits of tidal flats and estuaries where they occur in a complex association with solonchaks
- Very dry or arid parts of the dry zone where they occur in the inland valleys in association with low humic gley soils
- Terraces where they occur in association with soils on old alluvium

This description is limited to the solodized solonetzic soils and not to the solonchaks, which are saline alkali soils without distinct profile development. Their occurrence is related to the presence of sodium salts in the parent material, and hence their presence together with solonchaks on the more clayey parts of tidal flats and estuaries. In the inland valleys of the semiarid regions, solodized solonetzic soils occur in the valley bottom positions that are enriched with salts leached from the adjacent highland and where the rainfall is insufficient to flush these out. There is also an appreciable accession of cyclic salts during the dry southwest winds. Locations of trapped drainage and nick points in the planation surfaces of the dry zone are also favourable positions for the formation of these soils. Where they occur on terraces, the terraces could be semi-recent or somewhat older.

A characteristic feature of the solodized solonetz is the columnar structured B horizon with typically rounded caps overlain by a well-defined eluvial A horizon. The main features of a solodized solonetz profile are illustrated in figure 10.

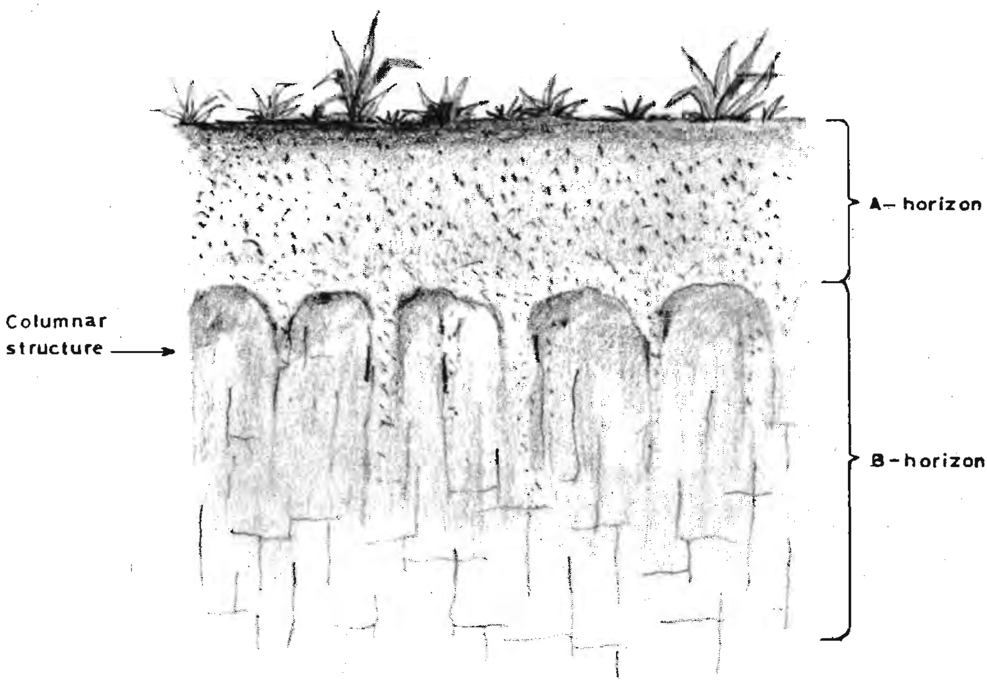

Figure 10: Illustration of a Solodized Solonetz.

The differentiation into the A and B horizons is very marked. The A horizon has a dark brown colour in its upper section, while in its lower section it is distinctly lighter and almost bleached. This soil horizon is usually coarse textured, structureless and is an albic horizon. It does not contain free salts, with the pH being neutral or at times even slightly acid. The B horizon contrasts sharply with the A horizon. It is usually grey to dark grey in colour and has very prominent mottling. Texture is moderately fine. The typical structure of the B horizon is the arrangement of the columns, which have a rounded bread loaf shape on the top; material from the A horizon penetrates the B horizon in tongues as shown in figure 10. The lower B horizon is commonly gleyed, and the exchangeable sodium percentage is greater than 15 and is, therefore, a natric horizon. Consistence of the soil material in the B horizon is very hard when dry and sticky when wet. The profile sequence is A1, A2, Bt (natric), Gg. The sodium in these soils has been present in the parent material when it was deposited in the tidal flats or estuaries.

In the soils of the second category, the A horizon is either thin or not so bleached, or it may even have been removed by erosion. The soils of the terraces have a well-developed A horizon with a bleached A2 horizon, and the B horizon is rather shallow.

The taxonomic placement of the solodized solonetz is:

Order - *Alfisols*
Suborder - *Aqualfs* (wet ones)
Great Group - *Natraqualfs* (sodium Natric)

In the World Soil Resources (WSR) map the placement is:

Major grouping - *Solonetz* (SN)
World Soil Map Unit - *Gleyic Solonetz* (SNg)

Vegetation in the tidal flats and estuaries is predominantly grassland with thorny scrub and few scattered trees. Halomorphic plants are found on the younger and therefore probably more saline soils, and at times even the grass cover is interrupted by numerous bare spots. The older solodized solonetz on the inland terraces has a more continuous grass cover with more bushes and stunted trees, as in the Kandakadu-Trikonamadu area where the dominant vegetation is *damana* parkland. The severity of the alkali conditions is reflected by the openness of the vegetation — the more severe the conditions, the more open the *damana*. Much of this area has since been cleared for irrigation development in system B of the Mahaweli.

4.7 REGOSOLS (Sandy)

These are soils formed on very recent transported material found along or near the coastline usually in elongated strips. In a dry zone environment, these would constitute formations such as barrier bars and spits, raised beaches, beach plains, and dune sands.

The sandy regosols found on the raised or elevated beaches and on the younger dune sands are the more extensive members in the dry zone. These regosols on the elevated beaches have, at most, a weakly humiferous surface horizon overlying a yellowish to brown sand. Texture of the soil material ranges from fine sand to moderately coarse sand. The sandy regosols on the young dunes have only an incipient thin surface humiferous layer, and the soil material is yellowish brown to very pale brown in colour. Both regosols contain a fair amount of weatherable minerals.

The sandy regosols on the somewhat older beaches have a more distinct humiferous surface horizon. But the soil material is composed almost entirely of whitish quartz sand without appreciable weatherable minerals.

Generally, the sandy regosols show no structure development and both the surface soil and subsoil are single grain, structureless, and with a loose consistence. Both surface soil and subsoil have a neutral reaction, and the base saturation in the subsoil is between 75 and 90 percent. Although the sandy regosols have a rapid infiltration, the infiltrated water is stored in the underlying static Gyben-Herzberg lens of fresh water, which permits good growth of deep-rooting tree crops.

There is another, probably older, form of sandy regosol on the Pleistocene terraces of the northwest coastal plain between Negombo and Chilaw. Such regosols, although quartzitic and without an appreciable amount of weatherable minerals, have a reddish colour caused by a ferruginous coating of single grains.

The bleached white sandy soils, earlier described by Joachim (1945) as Cinnamon soils, would also qualify as regosols on old sand formations. These, however, constitute the lowermost drainage member of the catena in this landscape where due to the fluctuating water table and the alternating oxidation and reduction, the ferruginous coatings have been removed.

The taxonomic placement of the sandy regosols is:

Order - *Entisols*
Suborder - *Psamments*
Great Group - *Quartzipsamments, Ustipsamments*

In the World Soil Resources (WSR) map the placement is:

Major Grouping - *Arenosols* (RF)
World Soil Map Unit - *Haplic Arenosols* (ARh)

4.8 SOILS ON OLD ALLUVIUM

The soils on old alluvium occur mainly in the old sandy depositional plain in the area between the lower Maduru Oya and the lower Mahaweli flood plain. These soils are found in a complex, or else in an association with other soils such as the noncalcic brown soils and solodized solonetz.

The old alluvial deposits are found in the wide valleys of the present and former river and stream systems that traverse this area. A distinction can be made between the older terraces that border the adjacent uplands, and the actual valleys in which are located the creeks and rivers, which drain the area. The difference in elevation between the valleys and terraces is very slight. Both the landscape and soil are subject to periodic waterlogging and, as a result, the subsoils are mottled.

The surface horizon consists of a dark greyish brown loamy coarse sand, which is underlain by a dark grey, yellowish to brown or pale brown, loamy coarse sand subsoil horizon. This subsoil horizon, in turn, overlies a dense lower subsoil that is gleyed. The transition between this upper subsoil and lower subsoil is abrupt and smooth. The dense subsoil horizon is usually impervious and the profile becomes saturated soon after the early seasonal rains.

The soils that occur on the terraces are pale brown imperfectly drained coarse sand, usually a meter or more in depth and overlies a greyish sandy clay loam of residual origin. At the transition, a thin stone line consisting of angular and subangular pebbles and gravels can be observed. The sandy topsoil is without structure. The underlying residual sandy clay loam is massive and sometimes contains calcium carbonate concretions.

The soils of the slightly incised valleys are, in most respects, similar to the soils of the terraces, except that they are usually deeper and sometimes the underlying residuum is not found within 2.5 meters of the surface.

In the soils of the terraces as well as in the soils of the incised valleys, no weatherable minerals are usually encountered. Soil reaction of the surface soil is medium acid to slightly acid. Base saturation of the subsoil is between 40 and 60 percent, and all plant nutrients are low.

The taxonomic placement of the soils on old alluvium is:

Order - *Entisols*
Suborder - *Psamments*
Great Group - *Quartzipsamments*

In the World Soil Resources Map (WSR) the placement is:

Major grouping - *Planosols* (PL)
World Soil Map Unit - *Dystric Planosols* (PLd)

The main vegetation associated with soils on old alluvium is low forest with open scrubland.

4.9 GRUMUSOLS

Although the total extent of these soils in the island is comparatively small, they provide a very good example of certain aspects of soil formation in relation to landscape and prior depositional history of the parent materials. They can be formed either from materials derived from basic igneous rocks such as basalts in India, or else from rich clayey parent material of varied origin. The grumusols of Sri Lanka are mainly formed on montmorillonitic material, which can be recent or semi-recent ponded alluvial clay, located within old slack water deposits of prior river systems. The original deposits could have been kaolintic, but because of the lateral inflow of groundwater from adjacent uplands charged with bases, the original material could have been converted to montmorillonite over a long period of time.

In the Tunnukkai area where the grumusols are best expressed, they are situated on sites of former slack water deposits of the Pali Aru, which river has since cut down and incised its river bed. A similar situation is encountered in the lower aspects of the adjacent Parangi Aru and the subsequent Nay Aru. Other situations conducive to their formation are the clays deposited in some of the abandoned tanks in the dry zone. A good example is also found in the southeast part of the Yala National Park around the former slack water depositional sites.

These soils do not have a B horizon in the natural state. They have only A and C horizons and are, therefore, said to have an AC profile. The colour of the A horizon is black or very dark grey brown, and the texture is usually a heavy clay with a clay content of more than 35 percent. At times a thin bleached surfaced sandy layer penetrates in tongues to the lower horizon. The clay of the A horizon is of the montmorillonitic type (smectite) as indicated by its high cation exchange capacity and also its swelling and shrinkage properties. Cracks up to 12 cm wide are formed when the soil dries out, and the alternate swelling and shrinking results in formation of the characteristic *gilgai* relief typical of these soils. This *gilgai* relief is typified by low mounds with depressions a few inches deep and a few square meters in surface area. Intensive churning of the soil produces slickensides, that is, grooved surfaces on the peds. With increasing clay content, these cracks, slickensides, and mulching become more pronounced. Secondary lime concretions are found in the lower part of the A horizon. Base saturation in the subsoil is between 65 and 90 percent and soil reaction is neutral. Clay mineralogy is dominantly smectite.

The type location for this great soil group is in Tunnukkai on the border between the Mullaitivu and Mannar districts. These soils are common in Asia and are referred to as the black cotton soils in India; the black cotton soils, in contrast, developed on basalts. Larger areas are also located in central and east Java where they were earlier referred to as margalitic soils; extensive areas occur around the central plains of Thailand.

The taxonomic placement of the modal member of these soils is:

Order - *Vertisols*
Suborder - *Usterts*
Great Group - *Pellusterts*

In the World Soils Resources (WSR) map the placement is:

Major Grouping - *Vertisols* (VR)
World Soil Map Unit - *Eutric Vertisols* (VRe)

The vegetation on these soils is extremely poor and consists of stunted trees interspersed with grass and bare patches. The usual tree species growing on these soils are abnormally stunted, and in the case of *Divul (Feronia limonia)* the lateral branches creep horizontally close to the ground. Thorn scrub predominates, and a few nonthorny shrubs are found widely scattered.

4.10 IMMATURE BROWN LOAMS (subgroup of the dry zone)

This subgroup is described here very briefly because it will be taken up in more detail under the wet zone soils.

The immature brown loams of the dry zone are mainly developed on residuum and colluvium of the micaceous Bintenne gneisses. They occur on the dissected middle level planation surface as well as on the transitional area between the intermediate planation surface and the middle planation surface. They also appear in scattered locations of areas with a marked relief and also on rock knob plains. North of Bibile, however, these soils are found on moderate slopes in places where the reddish brown earths have been entirely eroded after periods of intensive cultivation several centuries ago, and where the anthropomorphic savannah with an incomplete grass cover exposes a considerable surface of soil to further erosion.

The immature brown loams are shallow soils with a high proportion of unweathered or partially weathered primary minerals. The surface horizon consists of a dark brown to dark greyish brown sandy loam underlain by a yellowish brown to brown sandy loam, which is a sandy clay loam subsoil horizon. Numerous unweathered mineral particles are observed in both horizons, especially micas if the parent materials are micaceous. The surface soil has a weak to moderate crumb structure. The base saturation of the subsoil is between 40 and 60 percent and soil reaction is slightly acid to neutral.

The taxonomic placement of this subgroup is:

Order - *Inceptisol*
Suborder - *Ustrept*
Great Group - *Ustropept*

In the World Soils Resources (WSR) map the placement is:

Major Grouping - *Cambisols* (CM).

The savannah forest on these soils is almost entirely man-made, and is a consequence of burning and shifting cultivation. In the highly degraded savannah lands even shifting cultivation is not possible.

SOILS OF THE WET ZONE AND SEMI-WET INTERMEDIATE ZONE

4.11 Red-yellow Podzolic soils

The Modal group

Subgroup with strongly mottled subsoil

Subgroup with soft or hard laterite

Subgroup with prominent A1 horizon

Subgroup with semi-prominent A1 horizon

Subgroup with dark B horizon

4.12 Reddish Brown Latosolic Soils

4.13 Immature Brown Loams

4.14 Bog and Half Bog soils

4.15 Latosols and Regosols on Old Red and Yellow sands

4.11 RED-YELLOW PODZOLIC SOILS

The red-yellow podzolic soils are the modal soils of the wet zone of Sri Lanka, both in the lowlands as well as in the central highlands. Soils belonging to this great soil group were, and still are, referred to as lateritic soils, lateritic loams, etc., usually with a qualifying adjective such as red, yellow, reddish to yellow and gravelly, etc., to differentiate individual members. The earlier term lateritic does not necessarily indicate the presence of laterite, but more the earlier criterion of the low silica-sesquioxides ratio of less than 2.0, which differentiated the lateritic from the non-lateritic soils. The term red-yellow podzolic is, however, the accepted terminology for these soils, which are now recognized as the more widespread and dominant soils of the humid tropics of Asia. Besides the modal group, the following subgroups are recognized:

- Subgroup with strongly mottled subsoil
- Subgroup with soft or hard laterite
- Subgroup with prominent or semiprominent A1 horizon
- Subgroup with dark B horizon

The Model Group

This is the most widespread great soil group in the wet zone of Sri Lanka. The central concept of the red-yellow podzolic soils is not as yet sharply defined as that of the reddish brown earths for which a larger body of soil survey data has been available. It is hoped that with further progress of the soil survey investigations now being conducted in the wet zone of the country, a sharper definition will become available in the future, which would also permit the appropriate type location to be determined.

Soils belonging to this great soil group are developed on a wide variety of parent materials. These are mainly residuum, colluvium or local alluvium derived from a wide variety of Precambrian crystalline metamorphic rocks belonging to the Highland series and Southwestern group. It would also include some of the older alluvium of river terraces such as those found along the Kaluganga valley. The red-yellow podzolic soils occur on diverse landforms, but the majority are found in the hilly parts of the country. Admixture of rock fragments is common on all sloping land, and the steeper members tend to be more stony or rocky. The other subgroups are related to the physiography of the landscape as will be discussed later. Illuviation of clay appears to be a dominant process in the development of the red-yellow podzolic soils as seen in the distinct clay coatings on the ped surfaces. They have a distinct argic horizon.

The red-yellow podzolic soils are the dominant soils of the wet zone and also of the higher elevations in the semi-wet and semi-dry intermediate zone. Relief, on the whole, is not a very important factor, but in the depressions these soils are replaced by the hydromorphic associates such as the meadow podzolic soils, alluvial soils or half bog soils.

In the modal soils under natural vegetation, the A horizon is differentiated into A1 and A2 horizons. The A1 varies in thickness and is not strongly pronounced or very humiferous. Under cultivation, the A2 horizon tends to become less distinct as a result of erosion and mixing with the A1 horizon. This phenomenon is very common in the hilly terrains, especially in the tea-growing regions, where the A horizon may be practically absent, or else, a new Ap horizon is formed on the former Bt horizon. In contrast to erosion, there is also the phenomenon of accumulation in the lower aspects of the slope where a thick A horizon develops, which is neither very prominent nor very dark coloured. Profiles that have more than 50-75 cm of this young colluvium without a clear horizon differentiation will have to be excluded from this great soil group.

The colour of the A1 horizon is dark grey brown to dark brown; the predominant colour of the A2 is a strong brown to yellowish brown. These brownish colours persist under cultivation unless the A horizon is entirely eroded. The predominant texture of the noneroded A horizon is either a sandy loam, sandy clay loam or loam. Structure of the A1 is usually weak to moderate crumb or granular. Weak, subangular blocky structures are predominant in the A2, but it could often be nearly structureless. The distinctness of the structure diminishes with cultivation. Consistence is friable.

Transition to the illuvial Bt or the argic horizon is usually rather distinct, but rarely abrupt; generally a B1 transitional subhorizon can be distinguished. The thickness of the Bt horizon is highly variable, but is usually more than 100 cm in profiles that have not been subject to strong erosion. A Bt horizon of 200 cm or even 300 cm is no exception among soils of this group. The colour of the Bt is much redder than that of the A and always distinctly brighter (higher chroma). In a majority of the profiles the B2t is yellowish red, seldom red, but could be quite frequently of a brown to yellowish brown colour. There seems to be no distinct pattern in the occurrence of these colours and quite often reddish and yellowish brown colours can be observed side by side in a single profile exposure. Thus, no subgroup divisions could possibly be made on the basis of the color of the Bt horizon. The clay content of the Bt horizon is usually higher than that of the A horizon with the dominant texture being either sandy clay loam or clay. Prominent clay coatings can be observed in all profiles of this group. Consistence is mainly friable when moist, or slightly sticky and slightly plastic when wet.

Base saturation of the subsoil decreases with increasing rainfall. In the modal soils, it is less than 25 percent and values of around 5 percent are recorded in the very high rainfall areas as well as in some higher elevations. Soil reaction is strongly acid. Analysis of clay minerals by Kalpage (1965), Kawaguchi and Kyama (1967), Tampoe (1989), Mapa (1992), and some other data show kaolinite as the dominant clay mineral with 10 percent or more of gibbsite, which indicates an advanced stage of pedogenic weathering.

The red-yellow podzolic soils are undoubtedly the dominant soils of the humid tropics of south and southeast Asia wherever nonbasic parent materials outcrop. They occupy more than half the total area of the country in Vietnam, Malaysia, and nonvolcanic Indonesia.

The taxonomic placement of the modal group is:

Order - *Ultisols*
Suborder - *Udults*
Great group - *Rhodudults, Tropudults*

In the World Soils Resources (WSR) Map the placement is:

Major Grouping - *Acrisols* (AC) and *Alisols* (AL)
World Soil Map Units - *Haplic Acrisols* and *Haplic Alisols* (ACr) and (ALh)

Proceeding from lowlands to uplands, the most important natural vegetation types under which these soils are formed are: (1) the lowland tropical semi-evergreen forest, (2) the sub-montane tropical semi-evergreen forest, (3) the montane temperate, and (4) the degraded dry montane or *patana* grassland. The subgroup with a prominent A1 horizon is mainly found under wet *patana* grassland, and the subgroup with a semi-prominent A1 horizon is mainly found under *kekilla* vegetation. It should be remembered that a large part of the natural vegetation has been cleared so that it is possible that the red-yellow podzolic soils may have been developed under other vegetational types as well.

4.11.1 Subgroup with Strongly Mottled Subsoil

This subgroup is best expressed in the semi-wet intermediate zone lowlands of the Kurunegala district. The soils of this subgroup are developed on residuum and colluvium of weathered quartzo-feldspathic gneisses and biotite gneisses, and are mainly confined to terrain that is not hilly but more subdued such as rolling or undulating. The main distinguishing characteristic compared with the modal member is the strongly mottled subsoil, which indicates the occurrence of a high water table during the rainy season. The Kurunegala soil series of the Kurunegala catena is the modal representative of this subgroup.

The colour of the surface soil is dark brown to reddish brown, and the subsoil shows the characteristic mottling with background colours of yellowish brown to brownish yellow and yellowish red, etc. The texture of the surface soil is loamy sand to sandy loam, and that of the subsoil is sandy clay loam to sandy clay. A significant amount of ironstone gravel and manganese oxide concretions over 2 mm diameter are present at depths of 50 to 100 cm within the sandy clay loam matrix. The profile sequence is usually A1, ABg, B1cn, B2tg, B3tg, C.

The surface soil structure is weak subangular blocky, and consistence is friable. The base saturation in the subsoil is between 20 and 30 percent; and soil reaction is medium to strong acid. The dominant clay mineral is kaolinite with a trace of gibbsite.

The taxonomic placement is *Tropudults*, and the WSR placement is *Ferric Acrisols* (Acf).

4.11.2 Subgroup with Soft or Hard Laterite

Many of the red-yellow podzolic soils that contain laterite concretions, boulders or slabs are not necessarily included under this subgroup. Soils of this subgroup should have hard laterite formed in situ at depths of less than 125 cm, and soft laterite at depths of less than 250 cm. The soft laterite may be complete cabook, in the sense that the whole mass becomes irreversibly hard upon drying, or else it may be "incomplete" with only the red mottles becoming hard upon drying.

Soils of this subgroup mainly occur on the slightly elevated higher ground in the southwest coastal plain and in the upland parts of the inland undulating planation surfaces of the low country wet zone. Where the relief is more accentuated, this subgroup can be found on the footslopes of the hills as could be commonly observed around Warakapola on the Colombo-Kandy main highway.

The soils of this subgroup are strongly weathered and the weathered zone itself is deep to very deep. The deeper subsoil consists of soft laterite that hardens either massively or as gravel. In locations where erosion has been active, the laterite gravels are exposed on the surface. The Boralu soil series of the Boralu catena, which has been mapped in the coconut and rubber growing areas of the southwest of the country, can be considered the modal representative of this subgroup.

The colour of the surface soil is dark grey brown to dark brown, and the subsoil is yellowish brown to brownish yellow with strong mottling at the lower depths. The texture of the surface soil is sandy loam to sandy clay loam, and that of the subsoil is sandy clay loam with varying amounts of ironstone gravel.

The base saturation of the subsoil is between 15 and 30 percent; and soil reaction is strongly acid. The mineral weathering has reached a very advanced stage, so much so that very resistant minerals are concentrated in the coarse soil fraction, while kaolinite and oxides of iron and aluminum are predominant in the clay fraction.

Significant extents of soils of this subgroup are found in the more humid regions of Asia. The type location of laterite is best expressed in Malabar in the Kerala state of southwest India. In Sri Lanka, the Gampaha district could be considered the type location.

The taxonomic placement is *Plinthudult*, and the WSR placement is *Plinthic Acrisol* (ACp).

4.11.3 Subgroup with Prominent A1 Horizon; Subgroup with Semi-prominent A1 Horizon; and Subgroup with Dark B Horizon

All three subgroups are discussed together because of their close interrelationships.

The *subgroup with prominent A1 horizon* is found under wet grassland vegetation (wet *patana*) on the rolling topography of the upper level planation surfaces in close association with the subgroup with a dark B horizon. These are situated in the high altitude plateau of the Nuwara Eliya district at elevations around 2,000 meters. The *subgroup with semi-prominent A 1 horizon* is found under fernland *(kekilla)* and grassland vegetation on the rolling to hilly topography of the intermediate planation surface of the inland southwest parts of the island at elevations between 300 and 1,000 meters.

The *subgroup with a prominent A1 horizon* consists of a very dark brown to very dark grey loam or sandy loam horizon underlain by a yellowish brown sandy clay loam horizon with some mottling in the lower depths. The organic matter content of the surface horizon is high with a carbon content of 5-15 percent.

The base saturation of the subsoil is between 5 and 10 percent and the soil reaction is medium acid. Because of the advanced stage of mineral weathering in this environment, the coarse fraction of the soil contains many resistant minerals, while the clay fraction consists of 1:1 clays and hydrated oxides of iron and aluminium.

The taxonomic placement is *Tropohumult*, and the WSR placement is *Humic Acrisol* (ACu).

The *subgroup with semi-prominent A1 horizon* consists of a very dark grey brown gravelly clay loam horizon underlain by a brown to yellowish red gravelly clay loam horizon. The organic matter content of the surface horizon is between 2 and 5 percent carbon. The base saturation of the subsoil is extremely low, around 5 percent, reflecting the very advanced stage of weathering of these soils. Soil reaction is medium acid. The clay minerals are mainly kaolinite together with gibbsite and iron oxides.

The taxonomic placement is *Tropudult*, and WSR placement is *Humic Alisol* (ALu).

Soils of the *subgroup with a dark B horizon* show a dark-coloured horizon that coincides with the upper part of the B1 horizon. This dark colour is apparently caused by humus infiltrating from above. This horizon is usually 5 to 15 cm thick and is very distinct. However, this dark colour does not necessarily indicate a higher humus content as revealed in laboratory analysis, and may be probably due to a particular combination of clay and humus. Base saturation of the subsoil is between 5 and 15 percent and soil reaction is strongly acid. The soils of this subgroup occur mainly under montane forest on the upper and mid-slopes of the rolling to hilly topography. Soils of this subgroup occur in very close association with the subgroups with a prominent A1 horizon, and have very similar soil characteristics except for the dark B horizon.

4.12 REDDISH BROWN LATOSOLIC SOILS

The occurrence of the reddish brown latosolic soils in the dissected plateau and associated land surfaces of the middle peneplain of the island has an important bearing on the age and genesis of this great soil group. Most, if not all, of these soils occur on terrains that have been strongly incised by geological erosion. Since they have developed on a rejuvenated relief, the reddish brown latosolic soils are relatively young soils. The parent materials on which the reddish brown latosolic soils are found are mainly residuum and slope colluvium from the basic and intermediate rocks of the khondalite series. There are also a few members associated with quartzites and acid charnockites.

The reddish brown latosolic soils are best expressed within the 1,900 and 2,500 mm rainfall isohyets. Below 1,900 mm, they are replaced by reddish brown earths and when the rainfall is over 2,500 mm the red-yellow podzolic soils are dominant. They are best expressed in the wet zone part of the Kandy plateau, and in the transitional planation surfaces around Matale, Dodangaslanda, Galagedera, Rambukkana, and Mawanella and also around Middeniya in the south. In some landscapes, the reddish brown latosolic soils occur on the gentle lower slopes of the rolling landscape, while the immature brown loams occupy the upper slopes of the same landscape. Because of their excellent physical properties, their depth and resistance to erosion, they are among the most productive soils of the mid-country.

In the modal soils, the colour of the A horizon varies from reddish brown to brown and is always distinctly darker than in the underlying horizons. The texture is mostly sandy clay loam, and structure is strong crumb to granular under natural vegetation with a definite loss of structure in most cultivated soils. Consistence is friable. Primary minerals, most frequently micas, are always found in this horizon.

Transition to the illuvial Bt horizon or the argic horizon is gradual. Clay content increases regularly with depth, the textures being generally sandy clay loam to clay loam. Clay coatings, often strongly developed, can be observed on the ped surfaces. The thickness of this argic B horizon varies considerably, from less than 75 cm in eroded profiles to more than 400 cm in normal profiles. Colour in this horizon is variable, ranging from red or reddish brown to dark reddish brown. In profiles developed on charnockite or those influenced by crystalline limestones, the colour is redder. The structure of the argic B horizon is well-developed subangular blocky and it has the characteristic shiny ped surfaces of Nitisols. The consistence is friable to firm when moist, and slightly hard when dry. This argic B horizon has the necessary diagnostic characteristics for these soils to be placed in the FAO-UNESCO soil unit of Nitisols (NT). Transition to the C horizon is gradual. The C horizon consists of residuum of decomposed rocks.

The base saturation in the subsoil is between 25 and 35 percent and generally lower than 35 percent. Soil reaction of the subsoil is medium acid. Because of their stable structure, high water-holding capacity and permeability, their physical properties could be described as very good.

Analysis of clay minerals by Kawaguchi and Kyuma (1967) and Mapa (1992) show kaolinite as the dominant mineral together with a small quantity of smectite and vermiculite. Gibbsite is absent, which is indicative of a less advanced stage of pedogenic weathering.

The type location for this great soil group is the Yatinuwara division of the Kandy district located within the Kandy plateau. Although these soils have been earlier described as reddish brown lateritic soils, the present terminology is considered more appropriate. The closest analogues of this group are found in the higher altitudes of Kenya, Ethiopia, and Tanzania; and in the lower altitudes of Indonesian Java, Central America, and Cuba. The Nitisols are among the most productive soils of the tropics and they are intensively used for plantation crops and food production.

The taxonomic placement of the modal members of the reddish brown latosolic soils is:

Order - *Ultisols*
Suborder - *Udults*
Great Group - *Rhodudults, Tropudults*

In the World Soil Resources Map (WSR) the placement is:

Major Grouping - *Nitisols* (NT)
World Soil Map Unit - *Rhodic Nitisols* (NTr)

Very little of the natural vegetation is left on these soils. The present forest reserve at Udawattakelle bordering Kandy city may be considered as a much disturbed forest which has a few patches of natural forest. Similarly, the forest reserve bordering the Central Agricultural Research Institute (CARI) at Gannoruwa may also be considered as representative of the natural vegetation. The typical man-made Kandyan mixed forest garden finds its best expression on these soils.

4.13 IMMATURE BROWN LOAMS

The immature brown loams of the wet zone, as originally identified and designated by this name by Joachim (1935), are young soils formed on surfaces that have been continuously exposed to erosion. They are generally formed on material derived from mica schists and other micaceous rocks. The parent material may therefore be an important factor in the formation of these soils, since they seem to be absent in materials derived from more acid rocks. The typical cambic B horizon associated with young soils can be readily observed in the soil profiles. Micas may be present in all horizons, usually with feldspar and hornblende in the B horizon and deeper.

In the wet and semi-wet mid-country, this soil group is found mainly below the 2,500 mm rainfall isohyet. They have also been observed to occur at higher elevations on steeply sloping terrain in the mid- and up-country intermediate zones on material derived from quartz feldspathic gneisses mixed with charnockitic gneisses. As described earlier, they occur in close association with the reddish brown latosolic soils, and these soil-landscape relationships have yet to be properly worked out. The immature brown loams of the wet and semi-wet intermediate zone are best expressed in the Kandy plateau, in the intermediate planation surfaces of Matale and Mawanella, and in the transitional area between the Kandy plateau and the Knuckles upland. In their local distribution, they are found scattered in small patches, while in the larger patches they occur in a complex pattern together with the shallow reddish brown latosolic soils.

The A horizon varies in thickness between 12 and 35 cm. Colour is dark brown to dark grey brown, and texture may vary from loam to sandy loam. Structure is moderate to strong crumb, and consistence is friable to loose. This horizon contains many undecomposed primary minerals, especially micas if the parent material is micaceous.

Transition to the B horizon is gradual. This is a typical cambic B horizon in the sense that it is lighter and brighter coloured than the A horizon, and at the same time it is darker than the C horizon. The colours range from dark yellowish brown to brown. There should also be no clay movement into this horizon, and therefore there should be no clay coatings on the ped surfaces. Texture is predominantly sandy loam or loam and, as in the A horizon, numerous unweathered primary mineral particles may be observed, especially micas if the parent material is more or less micaceous. Structure in this horizon is indistinct, often weak crumb and sometimes weak subangular blocky. Consistence is loose to friable when dry. Transition to the C horizon is gradual and clear, and is observed at a depth of less than 100 cm. The C horizon consists mainly of decomposed micaceous rock with the original rock structure often visible. At times, the B horizon rests directly on hard rock.

The base saturation in the subsoil is between 40 and 65 percent and generally higher than 35 percent. Soil reaction (pH) of the subsoil is usually higher than 5.5. The soils have a very rapid infiltration and low moisture retention properties.

Analysis of clay minerals by Mapa (1992) has shown kaolinite and smectite plus vermiculite in equal proportion, together with appreciable amounts of mica. The total absence of gibbsite is indicative of a very early pedogenic weathering stage in a humid tropical climate like that in the mid-country.

Several type locations are proposed for the different soil series within this great soil group. The Daulagala, Akurana, and Kundasale series are associated with coarsely crystalline parent material on hilly lands of low relief. The Mawanella and Menikhinna series are associated with similar parent material on hilly lands of low relief. The Pallekelle series is associated with finely crystalline parent material. True analogues of this soil have not been reported in soil literature, and hence Joachim's original terminology of 1935 is considered as most appropriate.

The taxonomic placement of these immature brown loams is:

Order - *Inceptisols*
Suborder - *Tropepts*
Great Group - *Eutropepts* and *Dystropepts* according to level of base saturation

In the World Soil Resources Map (WSR) the placement is:

Major Grouping - *Cambisols* (CM)
World Soil Map Unit - *Eutric* and *Dystric Cambisols* (CMe) and (CMd)

4.14 BOG AND HALF-BOG SOILS

These soils have been previously described by names such as organic soils, peat soils, muck soils, etc., and they are mainly confined to the low-lying lands of the west and southwest of the island. The popularly used term ill-drained lands of the low-country wet zone is often used to refer to this group of soils. It was proposed by Panabokke (1977) that the term "ill-drained" be restricted to land that occupies the following landscape positions: (1) filled-up lagoons, (2) tidal marshes, (3) back swamps of major and minor river systems, and (4) narrow valleys of the hinterland that have constricted drainage outways.

The bog and half-bog soils are found within the filled-up lagoons, tidal marshes, and flood plains that occupy the coastal plain of the low country wet zone. The parent materials are mostly cumulose organic deposits overlying alluvium. The main soil-forming processes taking place in this environment are: (a) accumulation of parent materials mainly organic matter and mineral alluvium, (b) reducing processes with the formation of a gley horizon, and (c) leaching processes giving rise to acid soils poor in bases.

The bog soils have over 30 percent organic matter and consist of black to brownish black muck, mucky peat or peat (Dimantha 1977). The half-bog soils have less organic matter than the bog soils, but more than 15 percent of organic matter. The half-bog soils occur at a slightly higher elevation in the micro-relief where conditions for the breakdown of organic matter are better than in the lower position of the elevation.

The bog soils are strongly acid, the pH range being 4.5 to 5.5 in their natural wet state. Upon drying the pH of the soils can be lowered by 1.5 to 3.0 units. The cation exchange capacity of the organic material is very high but the base saturation is very low, usually between 2 and 20 percent. The bulk density of the soils is very low and the soils tend to, therefore, break up and float during high water conditions. The half-bog soils have a higher bulk density than the bog soils and thus have a better bearing capacity and anchorage. Their chemical properties are similar to the bog soils. The more important properties and the characterization of the different categories of bog and half- bog soils have been described by Dimantha (1977), to which the reader is referred for more information.

The taxonomic placement of the bog soils is:

Order - *Histosols*
Suborder - *Hemmists, Saprisits*
Great Group - *Tropohemists, Troposaprists*

In the World Soils Resources (WSR) map the placement is:

Major Grouping - *Histosols* (HS)
World Soil Map Unit - *Terric Histosols* (HSs) and *Fibric Histosols* (HSf)

Present vegetation in most of the area consists of grasses (*Panicum* species) and sedges (*Cyperus* species), mixed vegetation of marsh-specific species, and a few tree species.

4.15 LATOSOLS AND REGOSOLS ON OLD RED AND YELLOW SANDS

These soils are essentially an extension of the red-yellow latosols of the dry zone into the wet and intermediate zone rainfall regimes. Their geomorphological history is the same as the latosols, but the weathering processes have proceeded further because of the higher rainfall in this region when compared with the dry zone latosol climate. This is clearly reflected in the mineralogy of the fine sand and clay fractions.

These soils have been characterized and mapped as the Madampe catena in the Kelani-Aruvi Soil Survey (1963). Three catenary members were described: (1) the well-drained, dusky red Rathupasa series, (2) the imperfectly drained, yellowish brown Madampe series, and (3) the poorly drained white to light grey Sudu series. Accordingly, the Rathupasa would correspond to the latosols on old red sands, the Madampe to the latosols on old yellow sands, and the Sudu to regosols on old sands. Their profile characteristics are described in detail in the Kelani-Aruvi Soil Survey Report (1963).

The physical and chemical analysis of the Rathupasa and Madampe series indicate a low clay content, some illuviation of clay, a very low percentage of silt, and a very high percentage of fine sand. Soil reaction is slightly acid, and base saturation of the subsoil is very low.

The taxonomic placement of these soils is *Quartzipsamments*.

In the WSR map they are identified as *Rhodic Ferralsols* and *Xanthic Ferralsols*.

There is little or no original vegetation left on these soils. The total extent of these soils is under coconut cultivation and homestead gardens.

4.16 OTHER GREAT SOIL GROUPS AND MISCELLANEOUS LAND UNITS

Some other great soil groups of minor extent and therefore not shown in the General Soil Maps are briefly described here. A brief explanation of the miscellaneous land units as shown in the soil map is also given.

Rendzinas

These soils have been commonly called rendzinas or rendzina soils. They occur in the low-country dry zone as well as in the mid-country intermediate zone and are restricted to locations where crystalline limestone is present. They are formed on soft limestone or on weathered hard limestone. Their presence is indicated by the occurrence of outcrops of the underlying limestone rock.

The surface soils are dark brownish black in colour and have a sandy clay loam to clay loam texture. Structure is moderate crumb and consistency is friable. Soil reaction or pH is between 7 and 8, and a high base saturation is typical of this surface horizon. Soft limestone fragments are found mixed with the soil. The soils are underlain by decomposing limestone rock and a B horizon is usually absent.

Representative type locations are found in Pallekelle, Naula, and Moragaswewa between Habarana and Sigiriya. For more details refer Tropical Agriculturist Vol. 117; pages 26 to 27.

Meadow Podzolic Soils

These soils have been observed only in the highland plateau areas around Nuwara Eliya, and are distinctly associated with the two subgroups of the red-yellow podzolic soils, one of which has a prominent A1 horizon and the other a dark B horizon. Two main factors that govern the expression of these soils are the cool humid climate and the periodically high groundwater. These soils are found in the depressional areas of the high plateau and the parent material is colluvial or alluvial valley fill of variable texture. For more details refer Tropical Agriculturist Vol. 117, pages 32 to 33.

Wet Mountain Regosols

These soils occur on very steep slopes. They have undergone natural erosion and considerable mixing by colluviation, and no longer have any recognizable genetic horizons except for a weakly developed surface A1 horizon. They have colours and textures similar to the red-yellow podzolic soils. These soils have variable depths but the shallower phases predominate. Due to their shallow general depth, they have limitations for supporting a good stand of vegetation and are therefore very fragile when deforestation takes place.

Lithosols

The lithosols are very shallow soils occurring on steep slopes or very rocky lands. Soil development is not sufficiently advanced for them to show any structure. They have slightly acid to medium acid reaction and sandy to loamy textures.

Miscellaneous Land Units

The General Soil Map of Sri Lanka shows three miscellaneous land units, namely, (1) rock knob plains and eroded land, (2) erosional remnants, and (3) steep rockland and lithosols. Description of rock knob plains and erosional remnants have been given in chapter 2. The eroded lands have been shown as a separate unit number 29 in the 1971 version of the General Soil Map. This unit occurs along the boundary between the red-yellow latosols landscape and the reddish brown earth landscape, and a greater part of it is floored by Ferruginous Basal Gravel. The size distribution and the depositional pattern of this gravel suggest a previous turbulent depositional environment that could have taken place during one or more interglacials or interstidials.

4.17 LATERITE

Laterite is defined here as sesquioxide, a rich humus-poor mixture of clay with quartz and other diluents that commonly occur as red mottles or reticulate patterns and which may be soft or irreversibly changed to hard pans or irregular aggregates. Contrary to the earlier-held view that laterite was the end product of tropical weathering, it is now becoming increasingly clear that the formation of laterite can be brought about by a variety of local combinations of landscape positions, weathering reactions , water relationships, and other factors. The fact that primary minerals are often observed within hard laterite concretions supports a rejection of the earlier held views.

Laterite can develop on a variety of parent materials. They may be residual over basic igneous rocks or acid to intermediate rocks. The Malabar laterite of India, which is derived from basic rock is of a superior quality for building purposes compared to the Sri Lanka cabook derived from intermediate to acid rocks. Whatever the source of material in which laterite forms, an adequate supply of iron is essential. In Sri Lanka and probably in the whole of southeast Asia, laterite formation is observed in those horizons that are being, or have been, influenced by periodically high water tables.

Sivarajasingham et al. (1962) state that laterite has been identified with four physiographically distinct landscapes, namely, (1) high level peneplain remnants, (2) colluvial footslopes subject to water seepage, (3) low level plains having high water tables or receiving water from higher land, and (4) residual uplands other than peneplain remnants. The genesis of laterite requires an enrichment in iron that can take place in a number of ways. Most of the low level laterite in Sri Lanka is formed through enrichment by a fluctuating water table and enrichment by laterally moving water. The undulating lowlands of the low-country wet zone satisfy the conditions for the presence of a fluctuating water table because of both the relief and rainfall; hence the best expression of laterite formation in this region. Laterite formation in the colluvial footslopes is best observed on the Colombo-Kandy road around Warakapola. High level peneplain remnants are found sparsely scattered in the modal dry zone, and frequently around the Ratnapura and Balangoda areas.

Soils that contains laterite are not necessarily poor soils, and the laterite in itself does not affect the agricultural value of a soil unless it appears abundantly at a shallow depth or unless it has hardened considerably.

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CHAPTER 5

The Soil Landscapes of the Island

Although a greater part of the island is made up of rocks of Precambrian age that belong to the most ancient and stable parts of the earth's crust, the land surfaces of this country show many features associated with a youthful geomorphology. Tectonic uplift during different periods followed by peneplanation has resulted in the formation of a variety of land surfaces of different ages.

The lowest peneplain shows a generally mature relief and drainage pattern. The presence of pediment plains and stone lines in the dry zone regions, however, is evidence of late Tertiary to Quaternary morphogenesis. A rejuvenation of the drainage system is evident in the incised nature of the major streams and rivers. This is specially marked in the southeastern part of the island in the lower Walawe Ganga and Kirindi Oya areas where mild block uplift of the underlying basement has taken place.

The middle peneplain, in contrast, shows an immature relief and drainage pattern. This is correspondingly reflected in the degree of soil development on rejuvenated relief in several parts of this peneplain. As would be expected, the general topography and drainage pattern of the highest peneplain are more abrupt and juvenile.

In general, it could be stated that the soils of the planation surfaces of this country could be considered comparatively young compared with the highly weathered, tropical soils commonly associated with old landscapes.

The depositional surface of the northwest coastal plain on which the red-yellow latosols are located and which is designated as an *upwarped Pleistocene coastal plain* in the proposed Geomorphological Map of Sri Lanka (1987), could be considered a comparatively older land surface. Because of its high permeability it has resisted the normal erosive processes associated with the high intensity tropical rainfall experienced in this area, and thus remained stable over a long period, except for slight upwarping of the underlying basement.

While the normal processes of geochemical weathering and soil formation could be keeping pace with the normal processes of landscape evolution and erosion, the total depth of the soil overburden and decomposing parent material is never very great on these planation surfaces. Except for the latosols, the soils of most of the other great soil groups, especially those of the dry zone, rarely attain the soil depths commonly reported in adjacent India and neighbouring Asian countries. By international standards, the soils of the planation surfaces of Sri Lanka are considered only moderately deep with respect to their overall depth.

One of the more striking features of the soil distribution pattern in Sri Lanka is that one rarely encounters a large contiguous stretch or extent of a single great soil group as in the case of our neighbouring countries. The usual pattern in this country, as could be inferred from the legend of the general soil map, is an association of two or more great soil groups occupying a specific kind of landscape. The soil map of Sri Lanka is, in effect, the natural soil pattern of this country, which can be regarded as a logical expression of soil as a product of the interaction of climate, parent material, topography, groundwater, vegetation in so far as it is involved, and pedologic time.

The term landscape as used in this text is defined by Harris (1968) as a "stretch of country as seen from a particular vantage point." A soil landscape, or soilscape as it is sometimes referred to, is the pedological portion of the landscape. This could be depicted either in a three dimensional diagram or in a more simplified two dimensional diagram. It should be recognized that in Sri Lanka, more than in any other tropical country, a true appreciation of the soils essentially derives from a proper understanding of the different soil-landscape relationships.

At the level of generalization of the earlier 1971 Soil Map of Sri Lanka, which accompanied the Handbook of the Soils of Sri Lanka (1972), a total of 15 soil map units for the dry zone and a total of 12 soil map units for the wet zone were demarcated. Each of these map units may be considered equivalent to a soil landscape. In the soil map of the National Atlas of Sri Lanka 1988, which is the same as that attached to this publication, the number of soil map units shown for the dry zone is only 11, and that for the wet zone is 12, the same number as in the 1971 soil map.

In this chapter, the main features of seven soilscapes of the dry zone and four soilscapes of the wet zone are described in a manner that would help to bring out the more significant soil-landscape relationships. In the latter part of this chapter, a grouping of the presently identified and mapped soil series of the dry and intermediate zones of this country, according to the physiographic units in which they occur, will be presented.

5.1 THE SOIL LANDSCAPES OF THE DRY ZONE

Map Unit 1.	Reddish Brown Earths and Low Humic Gley Soils-Undulating Terrain
Map Unit 2.	Reddish Brown Earths and Solodized Solonetz-Undulating Terrain
Map Unit 3.	Reddish Brown Earths, Noncalcic Brown Soils, and Low Humic Gley Soils-Undulating Terrain
Map Unit 4.	Reddish Brown Earths and Immature Brown Loams-Rolling, Hilly and Steep Terrains
Map Unit 5.	Noncalcic Brown Soils, Soils on Old Alluvium and Solodized Solonetz-Undulating Terrain.
Map Unit 6.	Red-Yellow Latosols-Flat Terrain
Map Unit 11.	Regosols on Recent Beach and Dune Sands-Flat Terrain.

Map Unit No. 1 ***Reddish Brown Earths and Low Humic Gley Soils-Undulating Terrain***

As shown in the general soil map (see map in folder), this map unit no. 1 extends across a greater part of the lower planation surface. It covers the whole of the districts of Anuradhapura, Vavuniya, Polonnaruwa, Trincomalee, and Hambantota and parts of the Puttalam, Kurunegala, Matale, Ampara, and Moneragala districts.

The type location for this map unit could be taken as the central portion of the Anuradhapura district where the dominant landform is the "mantled plain undulating." Figure 11 shows the manner of distribution of the soils of this unit, on this landform.

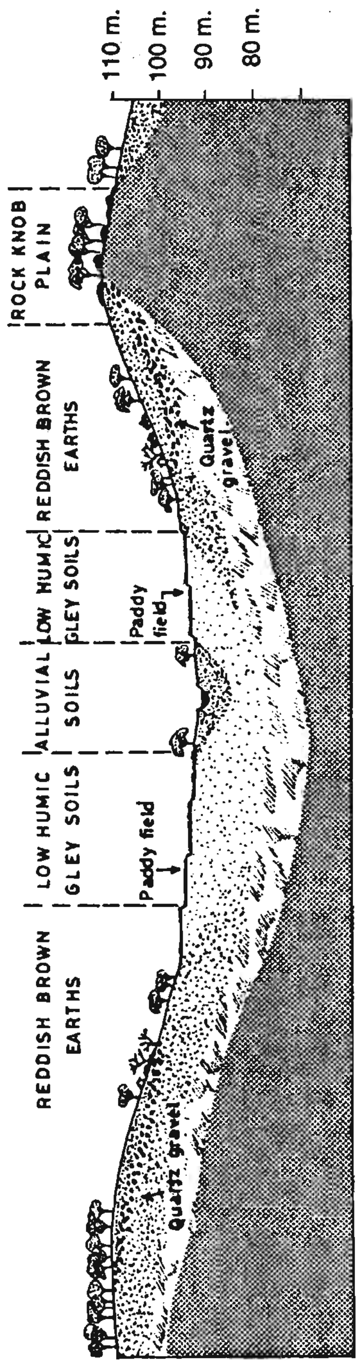

Figure 11: Reddish Brown Earth - Low Humic Gley Soilscape.

The reddish brown earths occupy the crest and the upper and mid-slopes of the landscape. The low humic gley soils occupy the lower parts of the slope and upper parts of the valley bottom. A narrow strip of alluvial soils occurs along the natural drainage stream. In the modal soilscape, the reddish brown earths occupy around 60 percent of the land surface, the low humic gley soils around 30 percent, and the remaining 10 percent is made up of alluvial soils and rock knob plains.

Variations from the above distribution pattern can be observed in the different topographic classes of the mantled plain. For example, in the level mantled plain found around Vavuniya district and the northwest portion of Anuradhapura district, the ratio of reddish brown earths to low humic gley soils is around 50:50. Likewise, in the rolling mantled plain that is found in the Walawe-Moneragala areas the ratio of reddish brown earths to low humic gley soils is 80:20.

Further geomorphological subdivisions of the mantled plain could be made accordingly to physiographic characteristics. A good example is the four different planation surfaces described by Somasiri (1992) for the Anuradhapura district:

1. Galewela-Kekirawa dissected intermediate planation surface
2. Ritigala-Padaviya dissected intermediate planation surface
3. Siripura planation surface
4. Anuradhapura planation surface

According to Somasiri (1992), each of the above geomorphic units consists of a distinctive combination of landforms, which has a close relationship to the soils, soil drainage conditions, and hydrology.

Two variants of this soil map unit no.1 were demarcated in the 1971 soil map of Sri Lanka as:

- Reddish brown earths with moderate amount of gravel in subsoil, and low humic gley soils; undulating terrain
- Reddish brown earths with high amount of gravel in subsoil, and low humic gley soils; undulating terrain

These two map units differ from the map unit no.1 in the amounts of quartz or ironstone gravel and pebbles present in the subsoil. The first of these is mainly present in the Puttalam district and adjacent parts of the Kurunegala district, while the second is mainly present in the southern parts of the Hambantota district and eastern parts of the Mannar district.

Map Unit No. 2 Reddish Brown Earths and Solodized Solonetz-Undulating Terrain

This map unit is best expressed in the very dry part of the dry zone across the southern part of the Hambantota district, and also in a small portion of the Moneragala and Trincomalee districts.

The type location for this map unit could be taken as the undulating mantled plain of the lower Walawe Ganga or the Kirindi Oya. This map unit is shown as the Ranna soil association in the earlier medium intensity soil surveys conducted for these two river basin development projects by de Alwis (1963) and Jayasooriya (1976). Figure 12 shows the manner of distribution of the soils of this unit, on this landform.

The reddish brown earths occupy the crest and the upper and mid-slopes of the landscape. The solodized solonetz occupies the nearly flat bottom lands. In the modal soilscape, the reddish brown earths cover between 70 and 85 percent of the land surface and the solodized solonetz between 10 and 25 percent of the land surface. Some inclusions of lithosols on the landscape summits, and small extents of low humic gley soils and alluvial soils in the valleys, are not uncommon.

Map Unit No. 3 Reddish Brown Earths, Noncalcic Brown Soils, and Low Humic Gley Soils -Undulating Terrain

This map unit consists of two different kinds of soilscapes. The first, which is found in northern Kurunegala district, mainly Maho, and adjacent parts of the Puttalam district, is the more representative form where the moderately fine textured noncalcic brown soils occur in close association with reddish brown earths. The type location for this soilscape is around Maho. The second, which is found in the Ampara and Batticaloa districts, is mainly an association of coarse textured noncalcic brown soils and low humic gley soils without any reddish brown earths. This second soilscape corresponds to soil map unit no. 7 in the 1971 version of the general soil map of Sri Lanka. The type location for this soilscape is around Uhana in the Ampara district. Figure 13 shows the manner of distribution of the soils on the first kind of soilscape.

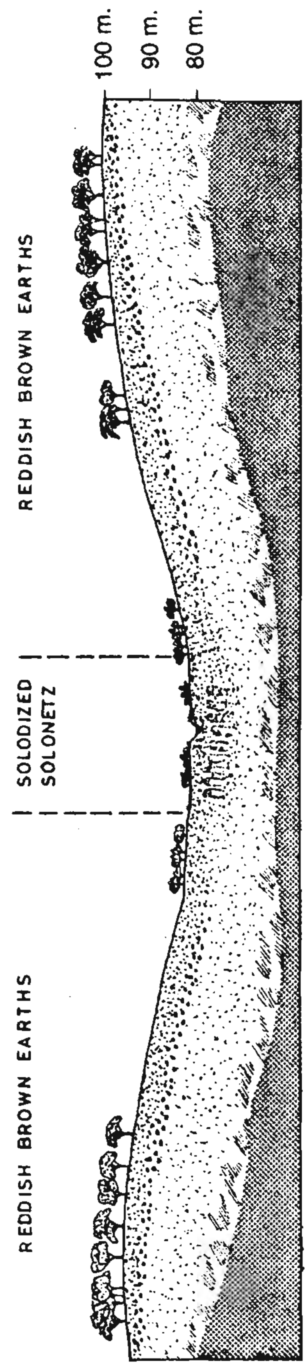

Figure 12: Reddish Brown Earth - Solodized Solonetz Soilscape.

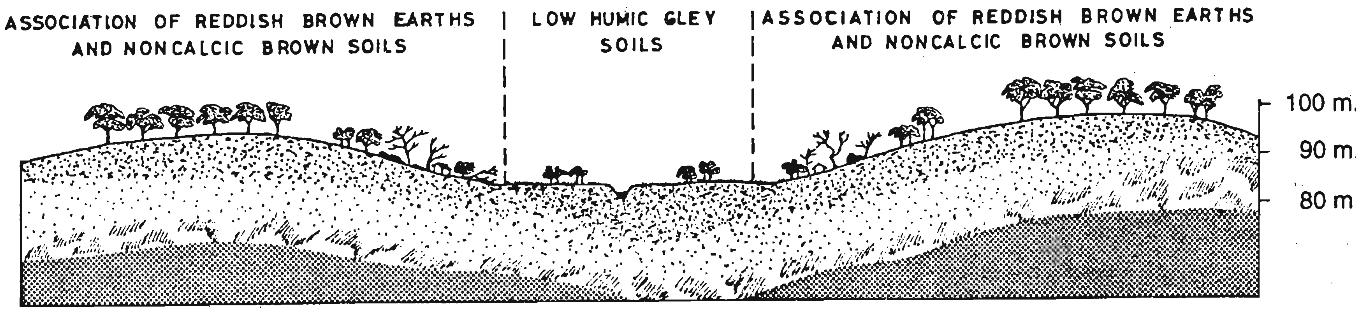

Figure 13: Reddish Brown Earth - Noncalcic Brown - Low Humic Gley Soilscape.

The reddish brown earths and the noncalcic brown soils occur in a complex association on the crests and the upper and mid-slopes of the undulating landscape. The content of ferromagnesian minerals in the parent materials determines the presence of either soil. The low humic gley soils occur on the lower slopes and valley bottoms. In a typical soilscape, the reddish brown earths occupy 20 to 40 percent of the land surface, the noncalcic brown soils 20 to 40 percent, and the low humic gley soils 15 to 30 percent of the landscape.

Map Unit No. 4 ***Reddish Brown Earths and Immature Brown Loams-Rolling, Hilly, and Steep Terrain***

This map unit is mainly present in the transitional dissected planation surfaces between the lower and middle peneplains, and it includes the corresponding portions of the Matale, Kandy, Badulla, Moneragala, Ratnapura, and Hambantota districts.

Because of the great diversity of landforms that make up this transitional planation surface, only a very generalized relationship between the soils and the landscape could be given. Figure 14 shows this general relationship.

The immature brown loams occupy a greater portion of the land surface, usually between 50 and 70 percent, and they occur on the steeper parts of the ridge and valley landform, the escarpments, and on the eroded slopes of the hilly terrain. The reddish brown earths occupy a smaller proportion of the land surface, usually between 25 and 35 percent. Inclusions of lithosols, low humic gley soils, and alluvial soils occupy between 5 and 15 percent.

Map Unit No. 5 ***Noncalcic Brown Soils, Soils on Old Alluvium, and Solodized Solonetz-Undulating Terrain***

This map unit is mainly confined to an area bordering the Polonnaruwa and Batticaloa districts and a small portion of the Trincomalee district east of Allai.

The type location for this map unit could be taken as the old sandy depositional plain that is situated between the lower Maduru Oya and the lower Mahaweli flood plain in the Tamankaduwa area. Figure 15 shows the manner of distribution of these soils in this very complex landscape made up of Bintenne gneisses and old alluvial deposits. This soil unit could be considered a typical soil complex rather than an association.

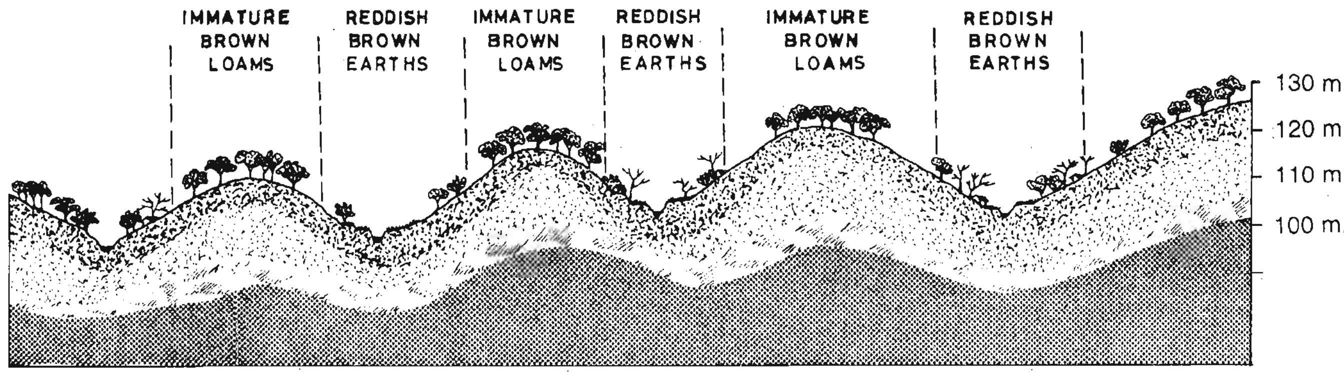

Figure 14: Reddish Brown Earth - Immature Brown Loam Soilscape.

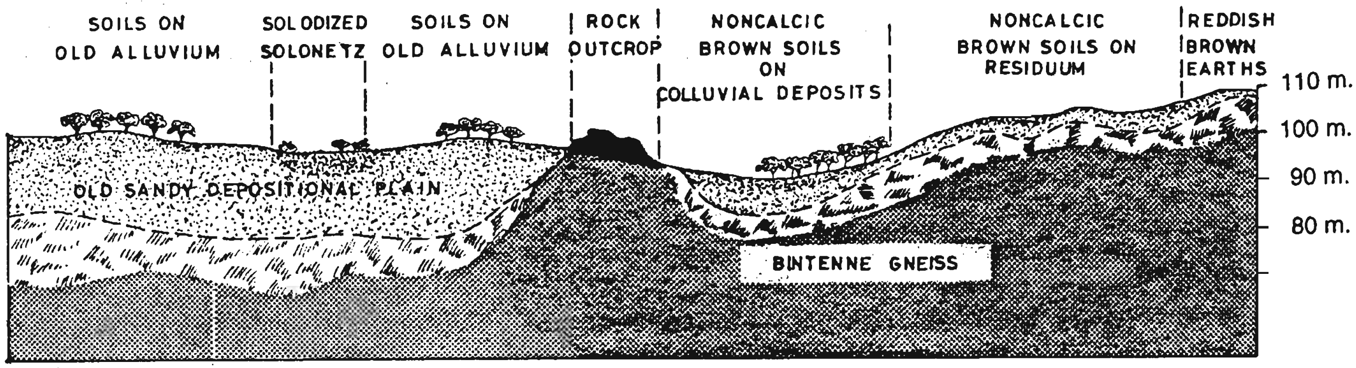

Figure 15: Non Calcic Brown Soil - Soils on Old Alluvium - Solodized Solonetz Soilscape.

The noncalcic brown soils mainly occupy the residual land surfaces of the Bintenne gneisses and their colluvial deposits. The soils on old alluvium occupy a greater part of the old sandy depositional plain and the solodized solonetz is mainly found in the micro-depressions. Small outcrops of coarse textured reddish brown earths could also be observed as shown in Figure 15.

Map Unit No. 6 Red-Yellow Latosols-Flat Terrain

The largest extent of this map unit is found in the Mannar district; smaller extents are found in the Kilinochchi, Puttalam, and Mullaitivu districts. A few isolated patches around Hambantota, Yala National Park, and Pottuvil-Komari in the southeast, show up on larger scale soil maps.

Several type locations could be proposed for this map unit. These are Vanathavillu in Puttalam district, Kondachchi cashew plantation in Mannar district, Chunavil in Kilinochchi district, and Puthukudiyiruppu in Mullaitivu district. These are all located on the old depositional surface of the northwest coastal plain. Figure 16 shows the manner of distribution of these soils on this landscape.

The red latosols occupy the crests, and upper-mid and lower-mid slopes of the gently undulating landscape. The yellow latosols occur in the lower topographical positions. Towards the coasts, the latosols overlie the Miocene limestone formations, while further inland they overlie the basement rocks. The basal ferruginous gravels are usually present within the boundary that separates the latosols from the underlying formations. The red-yellow latosols occupy over 90 percent of the land surface.

Map Unit No. 11 Regosols on Recent Beach and Dune Sands-Flat Terrain

This map unit is mainly present along or near the coastline in elongated strips, chiefly in the Puttalam, Batticaloa, Mannar, and Jaffna districts, and to a lesser extent in the other districts.

The type location for this map unit could be taken as the Kalpitiya peninsula in the Puttalam district. The type locations in the Batticaloa district are very similar, but those of the Mannar island and Jaffna peninsula could be considered as variants. Figure 17 shows the manner of distribution of these soils on this landscape.

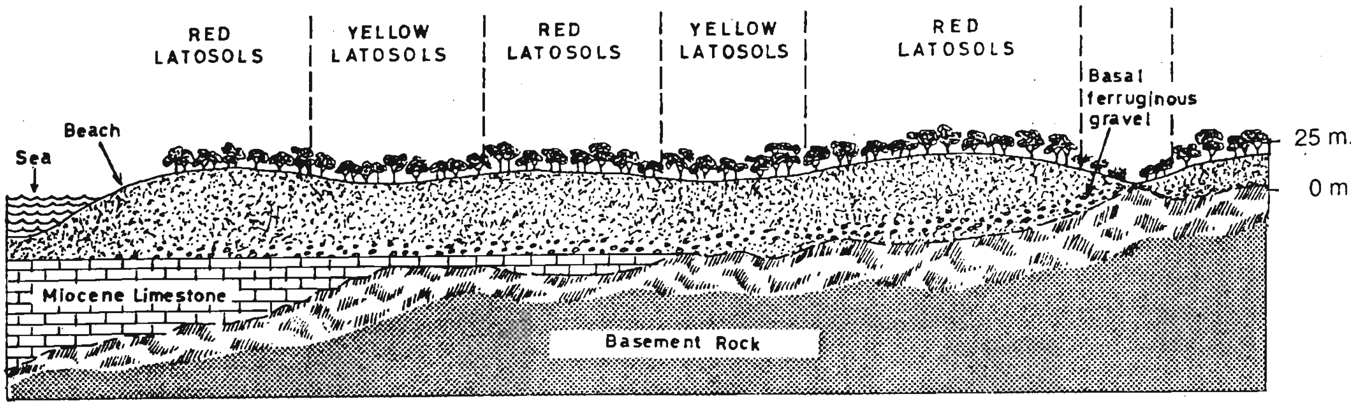

Figure 16: Red-yellow Latosol Soilscape.

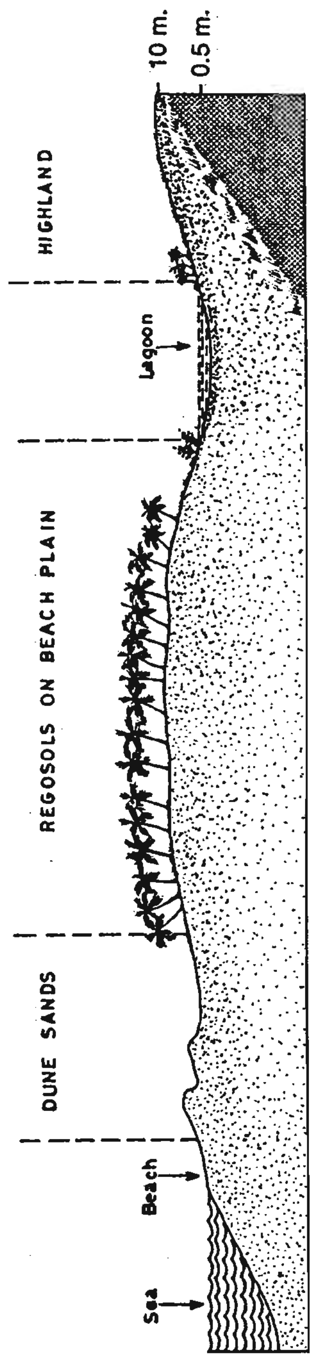

Figure 17: Coastal Sandy Regosol Soilscape.

The sandy regosols occupy the central portion and a greater part of the elevated beach plain adjacent to the lagoon. The dune sands are mainly present on the seaward side of the beach plain adjacent to the present beach. Of special significance is the underlying Gyben-Herzberg lens of fresh water that is present in the beach plains with a flat to gently undulating topography. This permits stable human settlement and agricultural production on this landscape even in the very dry environment.

5.2 THE SOIL LANDSCAPES OF THE WET ZONE

As stated earlier, the soils of the wet zone have not been characterized and mapped at the same level of detail as that carried out for the dry zone, except in some parts of the lower peneplain. Several workers have, however, recognized the need to understand the physiographic characteristics of the wet zone landscapes in order to arrive at a proper understanding of the soil-landscape relationships as well as for certain practical end uses.

The very uneven and highly dissected relief of the wet zone, which ranges from sea level to more than 2,500 meters, creates many varied physiographic conditions that have to be characterized and described in a systematic manner. Recognizing that relief is mostly responsible for the complexity of the wet zone, Desaunettes et alia (1974) have suggested what they term the "physiographic method" as the most appropriate approach to characterizing the morpho-ecological regions of the wet zone. They have identified five major *land systems* made up of *47 morpho-ecological regions*, based on their studies carried out during the period 1972- 1975. The main framework of the physiographic legend that has been proposed for purposes of land evaluation of the wet zone is given in table 3.

The hilly and mountainous system, which is made up of 23 morpho-ecological regions, is the most extensive and covers more than 50 percent of the total extent of the wet zone.

Table 3: Proposed Physiographic Legend for Land Evaluation of Wet Zone

System	Number of morpho-ecological regions
1. Alluvial and marine systems	4
2. Undulating plain system (elevation range, 5-60 m)	3
3. Hilly system (elevation range, 50-350 m)	9
4. Hilly and Mountainous system (elevation range, 300-1,200 m)	23
5. Mountain and plateau system (elevation range above 1,200 m)	8

Another important study on the land systems of the wet and intermediate zones in respect of rice lands, carried out during 1977-82 and published by Somasiri and Ratnayake (1988), has helped to characterize and demarcate the wide variety of landforms that have been developed for rice cultivation. The main differentiating criteria employed in their study are the regional physiography of the landscape, hydrological conditions, and select soil properties. Although these studies were specific to the understanding and management of rice lands located within the inland valleys of the wet and intermediate zones, the information has shed considerable light on the hydrology and some aspects of the pedology of the various soilscapes. Further aspects of this work will be discussed in a subsequent chapter on paddy soils and land systems.

While the foregoing studies were mainly focused on specific objectives relating to land suitability requirements for different end uses, they have, at the same time, helped in developing a better understanding of some of the soil-landscape relationships in certain regions of the wet and intermediate zones. However, until such time as the ongoing soil survey studies of the wet zone have made sufficient progress, it is possible only to broadly indicate the relationships of the soils to rainfall, elevation, and various forms of topography in the middle and upper peneplain regions. On the other hand, more definite descriptions of the relationships between the soils and landscapes in respect of the lower peneplain region can be made on the basis of the soil survey information available for this region.

Accordingly, *four map units*, namely 14,15,20, and 21, which are situated in the lower peneplain region will be described in the same manner in which the map units of the dry zone were described.

Map Unit 14	Red Yellow Podzolic Soils with Strongly Mottled Subsoil and Low Humic Gley Soils-Rolling and Undulating Terrain
Map Unit 15	Red Yellow Podzolic Soils with Soft or Hard Laterite-Rolling and Undulating Terrain
Map Unit 20	Bog and Half Bog Soils-Flat Terrain
Map Unit 21	Latosols and Regosols on Old Red and Yellow Sands-Flat Terrain

Map Unit No. 14 ***Red Yellow Podzolic Soils with Strongly Mottled Subsoil and Low Humic Gley Soils-Rolling and Undulating Terrain***

This map unit is best expressed in the low country semi-wet intermediate zone and is almost exclusively confined to the southwestern part of the Kurunegala district. Very small areas extend to the adjacent Kegalle and Ratnapura districts.

The type location for this map unit could be taken as the gently undulating mantled plain landform situated within about a 15 km radius area around Kurunegala city. Figure 18 shows the manner of distribution of the soils of this unit, on this landform.

The red-yellow podzolic soils with strongly mottled subsoils occur in the higher topographical positions and also on the mid-slopes of the landscape. The low humic gley soils of low base status occupy the lower parts of the slope and the upper parts of the valley bottoms. Narrow strips of alluvial soils occur along the natural drainage streams. There are prominent bare rock outcrops or inselbergs traversing this landscape.

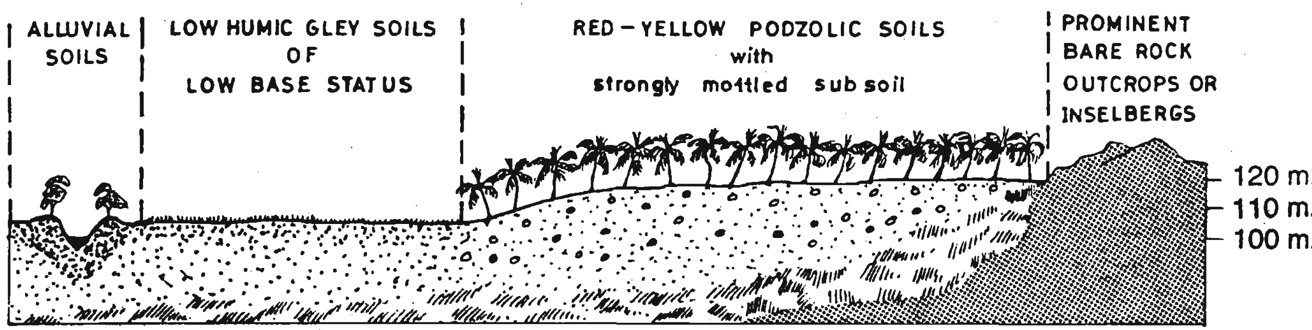

Figure 18: Red-Yellow Podzolic Soils with Mottled Subsoils.

In the modal soilscape, the red-yellow podzolic soils with mottled subsoil constitute around 70 percent of the land surface, the low humic gley soils of low base status around 20 percent, and the remaining 10 percent is made up of alluvial soils and lithosols of the rock outcrops. Variations from the above distribution pattern can be observed in the different topographic classes of the mantled plain.

Further geomorphological subdivisions of the mantled plain could be made according to the physiographic characteristics. Somasiri (1992) recognizes three planation surfaces, each with a distinctive morphology, within this soil unit area. These have a close bearing on the relative distribution of the member series of the Kurunegala catena.

Map Unit No. 15 ***Red-yellow Podzolic Soils with Soft or Hard Laterite-Rolling and Undulating Terrain***

This map unit is mainly confined to the low country wet zone regions, and it covers a larger part of the Gampaha and Colombo districts, as well as smaller portions of the Kurunegala, Kalutara, Galle, and Matara districts. The distribution of this soil unit within these districts is fairly well depicted in the soil maps compiled for these areas by the soil survey staff of the Coconut Research Institute. Although these soils are formed on colluvium and residuum from a range of basic and intermediate rock types, the relationships of these soils to the different parent materials are yet to be established. The mapping units of the Boralu and Homagama catena correspond to this map unit in the Gampaha and Kalutara districts. The equivalents south of the Kalutara district are yet to be clearly established.

A transect between Minuwangoda and Divulapitiya and a transect between Ragama and Mahara could be considered the most representative type locations for this map unit. The manner of distribution of the soils of this unit on this landscape is fairly straightforward and therefore needs no further elaboration. On the other hand, the relationship of this soil unit to its adjacent soil units, numbers 13 and 21, could be more instructive, and is therefore shown in figure 19.

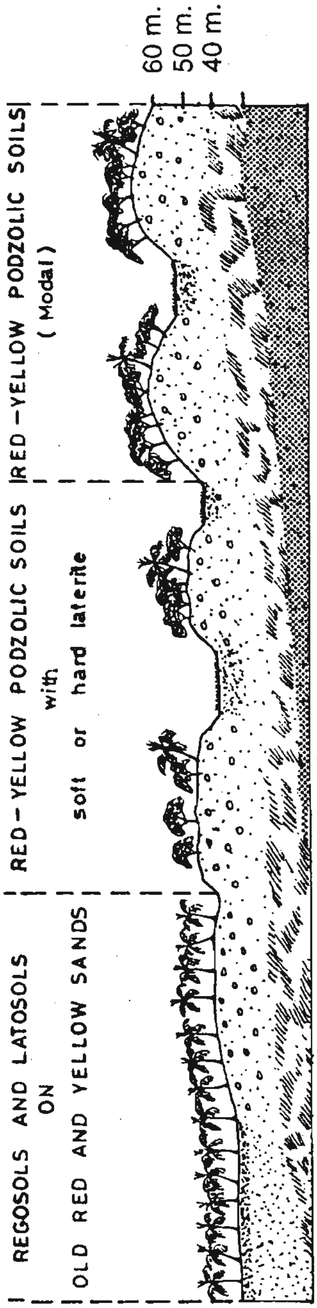

Figure 19: Red-Yellow Podzolic Soils with Soft or Hard Laterite.

Somasiri (1992) distinguishes two kinds of planation surfaces on which this soil unit occurs in the districts north of Kalutara, namely, the Gampaha-Padukka planation surface and the Horana planation surface. The former is described as a "featureless undulating planation surface having very low relief and with occasional erosional remnants", and the latter as an "undulating to rolling surface with isolated hillocks and low parallel ridges", These differences in the geomorphology of the two planation surfaces have a close bearing on both the quality and the nature of distribution of this soil subgroup on the landscape.

Map Unit No. 20 Bog and Half-Bog Soils-Flat Terrain

This map unit is mainly confined to the so-called "ill-drained lands of the low country wet zone", which are located in the lower coastal plain of the Gampaha, Colombo, Kalutara, Galle, and Matara districts. Well-known locations are Muthurajawela, Attidiya, Bolgoda lake, Madampe lake, Koggala, and Kiralakele. These locations correspond to those low-lying lands bordering lagoons, lakes and filled-up marshes, and these should be distinguished from the estuaries of major rivers, which carry a mangrove vegetation. Smaller extents are also found in the low-lying inland valleys located in the hinterland of the Ratnapura and Galle districts.

This map unit is made up of both bog and half-bog soils as well as an admixture of poorly drained alluvial soils. The main characteristics of these three broad soil groups, the bog soils, alluvial soils, and half-bog soils, as well as their relative positions in the very low relief landscape have been described by Dimantha (1977).

A major proportion of this map unit is located within the filled up lagoons and low-lying lands bordering lagoons and lakes, followed by those located within the backswamps of major river systems. Smaller extents are located in the narrow inland valleys with constricted drainage out-ways.

Two type locations are described for this map unit. The first in a tract of low-lying land bordering a lagoon in the Kalutara district (figure 20), and the second in a backswamp situation of a major river system, the Kelani Ganga, in the Colombo district (figure 21).

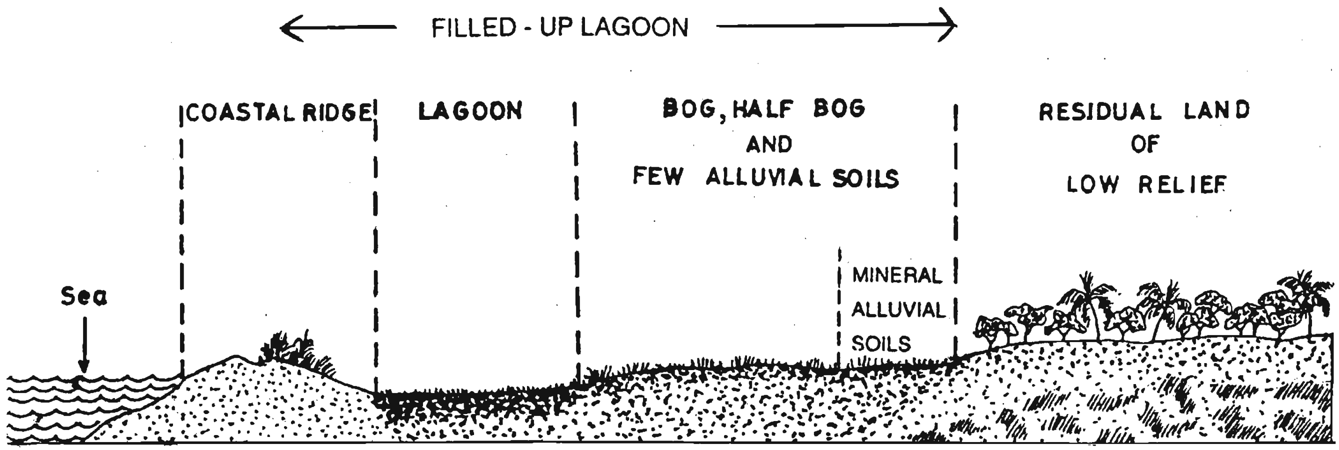

Figure 20: Bog and Half Bog Soils.

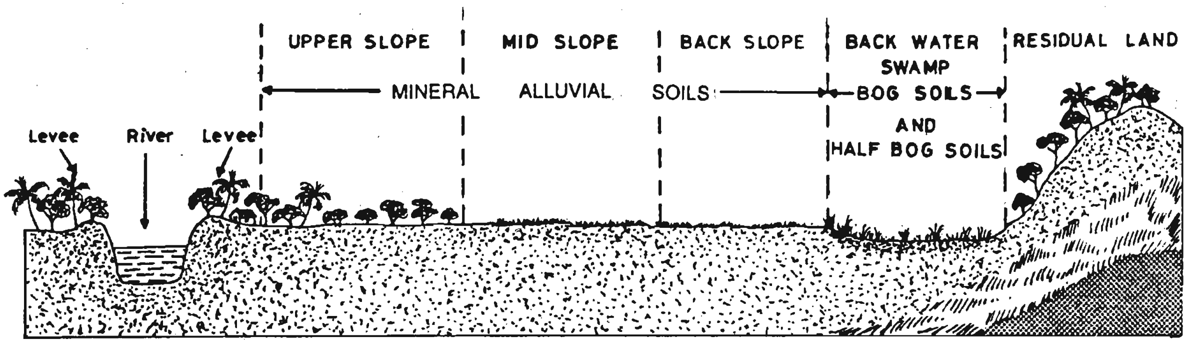

Figure 21: Cross Section of Alluvial Plain Showing Sequence of Soils and Hydrological Conditions.

As shown in figure 20, the filled up lagoon is located between the coastal ridge on the west coast and the residual land of low relief that borders the edge of the lagoon in the east. Soils of this map unit are distributed along the micro relief of the filled-up portion of the lagoon as shown in this figure. The bog soils occupy the lowest position at an elevation between 0 and 1.5 m above mean sea level, the half-bog soils occupy the intermediate elevation generally between 1.5 and 2.5 m above mean sea level, and the mineral alluvial soils at elevations higher than 2.5 m above mean sea level. Bearing in mind that the tidal range in this country varies between 45 cm and 60 cm during spring tide and approximately between 10 cm and 25 cm during neap tide, salinity intrusion will be mainly confined to the elevations within which the bog soils occur.

Figure 21 shows, in cross section, the profile of the landscape of the alluvial flood plain of a major river system. The bog and half-bog soils occupy the depression or the back water swamp of the river system, which is subject to frequent flooding and has a restricted drainage. The mineral alluvial soils occupy the slightly higher elevations of the micro relief. Depending on the nature of the river profile and the manner in which the flood plain has developed, the bog and half-bog soils could occur at elevations of up to 3.5 m above mean sea level (MSL) within the back water swamp.

Map Unit No. 21 Latosols and Regosols on Old Red and Yellow Sands-Flat Terrain

This map unit is exclusively located within the raised Pleistocene depositional plain that extends southwards from Chilaw through Negombo and terminates around Dehiwela-Mount Lavinia at its southern limit. The main Galle Road from the Galle Face Green in Colombo to Mount Lavinia skirts the Rathupasa and Madampe series throughout its 12 km stretch. The fashionable Cinnamon Gardens or Colombo 7 is mostly located within the Sudu series.

The soils of the Madampe catena that make up this map unit occur on an almost level to greatly undulating "coastal sand plain" landform at elevations ranging from 3 m to approximately 30 m above sea level. As shown in figure 22, the Rathupasa is located on the main ridge of the sand plain, the Madampe on the mid-aspect, and the Sudu on the lowest aspects. The regosols on the recent beach sands lie adjacent to the sand plain on the seaward side, and the red-yellow podzolic soils with soft or hard laterite or the Boralu series on the landward side.

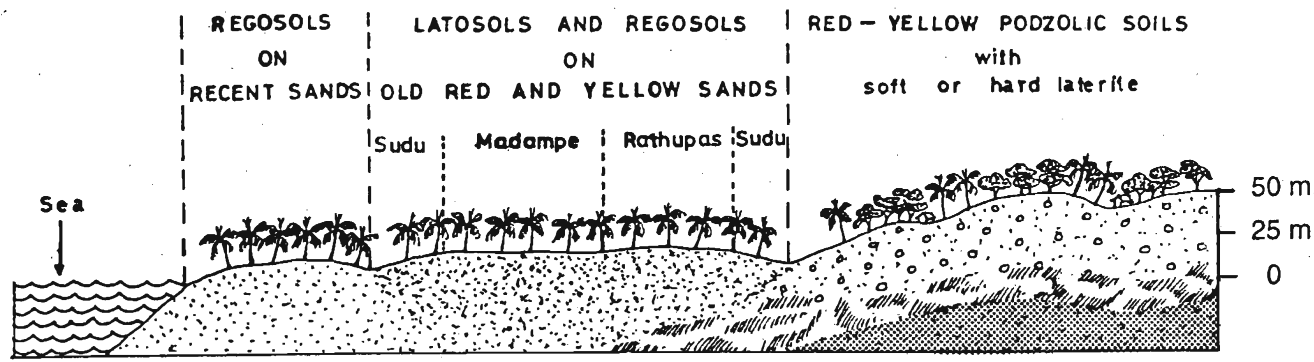

Figure 22: Regosols and Latosols on Old Sands.

Soil survey and land suitability studies conducted very recently by Somasiri, Amarasinghe, and Nadarajah (1993) within the so-called coconut triangle have helped to clearly elucidate the soil-landscape relationships both within the coastal sand plain and the adjacent undulating mantled plain.

An east-west transect across Marawila on the Chilaw one inch to one mile topographical sheet provides the best type location for this map unit.

The area occupied by the Rathupasa series is approximately 10 percent of the total area of this map unit. The Madampe and the Sudu series make up 50 percent and 40 percent, respectively.

5.3 A PHYSIOGRAPHIC GROUPING OF THE IDENTIFIED SOIL SERIES OF THE DRY AND INTERMEDIATE ZONES

In chapter 3, it was mentioned that approximately 250 soil series have been currently identified and mapped in this country since 1960, when systematic soil surveys commenced under the National Soil Survey and related programs of the Land and Water Use Division of the Irrigation Department and formerly of the Department of Agriculture.

Each soil series bears the name of the location where it was first identified. This place name, therefore, gives it a geographical position in various kinds of soil maps. Apart from the professional soil surveyor, the general reader should be able to get a sense of location of the particular soil series and even be able to identify it in the field.

More importantly, an individual soil series occupies a specific position of the landscape on which it occurs. All soil series identified and mapped in this country are assigned a specific position in the landscape. This helps the agriculturist and general user of soil maps to locate the particular soil series in the corresponding portion of a landscape.

In order to give the general user of soil information a general idea of the position in the landscape on which any one of the presently identified soil series normally occurs, a physiographic grouping of all soil series presently identified and mapped in the dry and semi-dry low country intermediate zones is presented in the subsequent subsections.

A total of 135 soil series identified to date are grouped under four main physiographic categories and several subcategories as shown below. For more detailed information on the boundaries and areal distribution of a particular soil series, reference will have to be made to the published soil maps available with the Land Use Divisions of the Irrigation and Agriculture Departments and other institutions; for example, the Coconut Research Institute for the coconut triangle area.

5.3.1 Soils of the Undulating Lowland Mantled Plain

5.3.1.1 Soils of the broad ridge crests and upper slopes

- Mainly reddish brown earths and some noncalcic brown soils

  Soil series: Alutwewa, Ranorewa, Tadaratu, Ihala, Kelegama, Medawachchiya, Etakanda, Nalanda, Maradanmaduwa, Walawe, Ranna, Nonagama, Tonigala, Kiriwana, Maduru Oya, Akurugoda, Ulhitiya, Manampitiya, Wilayaya, Palliyagodella, Migaswewa, Dehiaththakandiya, Malwatte, Andigama, and Maho

5.3.1.2 Soils of the mid-slopes and side slopes

- Mainly reddish brown earths and some noncalcic brown soils

  Soil series: Elayapattuwa, Ikiri, Balalla, Adipola, Muthugala, Welikanda, Ethbatuwa, Kuttigala, Mahagal Ara, Mawakulam, and Padumunda Kulam

5.3.1.3 Soils of the footslopes and lower slopes

- Mainly low humic gley soils

  Soil series: Anamaduwa, Cheddikulam, Hambegamuwa, Tabbowa, Wadigawewa, Alawakumbura, Galwewa, Nikawewa, Horaborawewa, Bowatte wewa, Ketagal ara, Siyambala, and Malabotu

5.3.1.4 Soils of the toeslopes and depressions

- Mainly low humic gley soils

  Soil series: Alubima, Huratgama, Labugama, Tuppaigama, Yala, Aluttarama, Ellegala, Kuda Oya, Kirimetiya, Kanngaswela, Kekuluwewa, Kohomba Ela, Mailadeniya, Kadewelwewa, Damminawela, Adipola, and Balalla

5.3.2 Soils of the Older Raised Beaches, Beach Ridges, and Near Shore Deposits

- Mainly red-yellow latosols

  Soil series: Gambura, Borupan, Wilpattu, Mavillu, Rathupasa, Madampe, Mullaitivu, Inuvil, Palali, Vaddukoddai, Bundala, Ariyali, Kumubuk, and Elavankulam

5.3.3 Soils of the Recent Beaches and Younger Beach Ridges

- Mainly sandy regosols

  Soil series: Negombo, Weliketiya, Puttalam, Aturuwela, Tetku, Navatkuli, Mathagal, Columbuthurai, Udappu, Kalpitiya, Mampuri, Madurankuli, Halawatha, and Norochcholai

5.3.4 Soils of the Alluvial Systems

- Mainly alluvial soils

5.3.4.1 Soils of the levees and adjacent backslopes

Soil series: Aluthnuwara, Kalinga Ela, Kirindi Oya, Bulatiebbe, Timbolketiya, Rambepitiya, and Elwitiya

5.3.4.2 Soils of the floodplains and minor valleys

Soil series: Handapanwila, Hembarawa, Moraketiya, Pallegama, Tissa, Aruvi, Timbiri Ara, Kaluganga, Kalu, Ambagaha Oya, Magama, Wadigawewa, and Saravanai

5.3.4.3 Soils of the backswamps and minor depressions

Soil series: Hungamala, Katuwanwila, and Hewampitiya

5.3.4.4 Soils of the terraces of major rivers

Soil series: Ulpothwewa, Moogamana, Kumarapuragama, Vakaneri, Arasanagar, Rajakadaluwa, Ambakelle, Welipellessa, Palugaswewa, Bangadeniya, and Kakapalliya

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CHAPTER 6

Classification of the Soils of Sri Lanka - Past and Present

6.1 INTRODUCTION

People have a natural tendency to sort out and classify the natural objects of their environment such as plants, animals, and rocks. Soils are no exception, being objects of common experience and observation and, even more, the very foundation of agricultural production for human sustenance. Classification should not be looked upon as an academic exercise because when applied properly it can be of very high utilitarian value. When we classify natural phenomena, we contribute towards organizing knowledge and thereby economy of thought, assist in remembering the properties of the objects classified, and also help in establishing groups or subdivisions of the objects under study in a manner useful for practical or applied purposes.

Early systems of soil classification were quite simple and practical. For example, the system of Richthofen (1886) had two main groupings of 'residual soils' and 'accumulated soils' and seven subgroupings each under these two main groupings. With greater knowledge about soils as a collection of independent natural bodies, and a greater complexity and diversity of soil uses, the classification of soils has become more scientific and organized. Any classification system undergoes revision as the body of knowledge on which it is based expands. This is very evident in the case of Sri Lanka, when we study the 1945 classification of the soils of Ceylon by Dr A.W.R. Joachim and the evolution in the classification of Sri Lankan soils to the present period.

Following the period of the founding of a Russian school of pedology under the leadership of Dokuchaev in the late nineteenth and early twentieth century, C.F. Marbut of the United States of America was instrumental in developing the first truly multi-categorical system of soil taxonomy in 1935. Marbut's approach was developed further by Baldwin, Kellog, and Thorp (1938), who introduced the concept of *zonal, intrazonal* and *azonal soils* at the highest categoric level of the soil order. Joachim's 1945 classification of the soils of Ceylon was in line with this system of classification that was in vogue up to the middle of this century.

The modern period of quantitative pedology begins with refinements to the categories of soil classification: the *order, suborder*, and *great soil group* by Thorp and Smith (1949) to the higher categories; and family, series, and type by Riecken and Smith (1949) to the lower categories. A comparison of botanical categories and soil categories is shown below.

Botanical Classification	**Soil Classification**
Phylum	Order
Order	Suborder
Class	Great Soil Group
Family	Family
Genus	Series
Species	Phase or Type

The *great soil* group is the most meaningful and also the most convenient method of typifying the soils of this country, and it is also one that best enables comparisons of our soils with the great variety of soils in the rest of the tropical world. Readers interested in more details regarding the classification of tropical soils are referred to chapter 4 of Dr Kalpage's publication, *Tropical Soils* (1974).

6.2 SOIL SURVEY AND CLASSIFICATION OF THE PAST

A minimum body of soil survey data should be available before any classification is attempted. Joachim and his co-workers started their soil profile studies and soil reconnaissance in the early 1920s, a period when support facilitates such as aerial photography, geological base maps, and jeeps for jungle traverses were not readily available. A systematic investigation of the soils of the island on a pedological basis was conducted by them over a period of nearly a decade, during which the basic data essential for a classification of the country's soils was painstakingly gathered. Their studies laid special emphasis on the genesis of the soils, their relations to environmental factors, the soil profile characters, and the nature of the clay complex. In 1945, Joachim proposed what he termed a scheme of classification together with a provisional soil map of the island on the basis of this classification.

His scheme of classification, reproduced below, contains three broad highest categories, *Zonal, Intrazonal*, and *Azonal*, in keeping with the prevailing classification system of that period, together with two other categories that he had introduced at the same level. This reflects the imperfections of the system of zonality that Joachim had to contend with, rather than imperfections in his scheme of classification.

1. Zonal Soils

Soils in which climate is the dominant soil-characterizing factor. These include:

(i) the reddish to yellowish laterite soils and lateritic loams formed under conditions of high rainfall and temperatures and derived from igneous and gneissic rocks
(ii) the red, reddish brown, and dark grey lateritic and nonlateritic loams of the "dry zone" of the island with an annual rainfall of 100-190 cm (40-75 inches), also derived form igneous and gneissic rocks.

2. Intrazonal Soils

Soils associated with limestone. They comprise:

(i) the brick red loams (terra rossa) derived from Miocene limestone in the north and northwest of the island
(ii) the grey calcareous loams (rendzinas) also derived from Miocene limestone
(iii) soils similar to the black cotton soils of India frequently associated with Miocene or dolomitic limestone
(iv) the chocolate red loams associated with or derived from crystalline limestone, mainly dolomite
(v) a small area of red loams over sandstone associated with Jurassic limestone.

3. Soils derived from Pleistocene and sub-recent deposits:

(i) the red and brown sandy loams
(ii) the bleached white sands (cinnamon soils) and the coastal sands.

4. The humic soils overlying reddish yellow laterite and lateritic loams and clays, including:

(i) the wet grassland *(patana)* soils
(ii) the dry grassland *(patana)* soils

(iii) the fernland *(kekilla)* soils
(iv) the low-lying peaty soils and *deniya* soils.

5. *Azonal soils*

(i) alluvial silts and loams
(ii) the paddy soils.

A general description of these 'major soil groups and series' is given in the *Tropical Agriculturist* Vol. 111, No. 3, 1955, pages 1-11. Readers interested in the state of the art of that period are referred to the very informative article in this journal. The analysis of Ceylon Soils, which appears at the end of this article is of very special significance and interest. Apart from physical and chemical analytical data, the general relationships of the soils to rainfall, geology and vegetation, and the use of silica/alumina ratio of the clay fraction in the separation of the lateritic from the nonlateritic soils come out very clearly in this analysis.

There has been considerable modification in respect of the relationships of the Azonal soils, particularly the so-called terra-rossa, which are now known to be influenced by, rather than derived from, limestone. Similarly, the black cotton soils are now recognized as being derived from montmorillonitic material rather than from limestone.

6.3 SOIL SURVEY AND CLASSIFICATION-1960-1970

The aerial photo coverage of the island carried out during 1956 under the Canada-Ceylon Colombo Plan project gave a major impetus to the conduct of soil surveys on modern lines in this country. The creation, in 1959, of the Land Use Division within the Department of Agriculture (later transferred to the Irrigation Department) and assigning it the responsibility of conducting the national soil survey of the country provided the essential institutional base for a systematic survey and classification of the island's soils resources along contemporary methods. An additional bonus from the Canada-Ceylon Colombo Plan project was the provision of a grant and technical expertise to conduct a soil survey along modern lines in collaboration with the staff of the Land Use Division of the Agriculture Department. This survey covered fifteen river basins between Malwathu Oya-Aruvi Aru and Kelani Ganga in the northwest of the country. The results of this survey, which covered an area of approximately 19,400 km^2

(7,500 square miles), has been published in two volumes under the title, *A Report on the Survey of the Resources of the Kelani-Aruvi Area of Ceylon* (1963) together with a soil map of 1:250,000 scale.

This marked the beginning of modern soil surveys in the country, and served as a model on which the future soil surveys of the country could be organized and conducted. The landform and soil survey was conducted using a combination of aerial photograph interpretation and field observations. The classification of the soils evolved gradually as the field surveys proceeded and was finalized after completion of the field work. The main mapping unit employed was the *soil catena*, which is made up of the component drainage members or soil series. These drainage members or series that make up the catenas were demarcated on the aerial photographs used in the field. The soil series and catena nomenclature are based primarily on local place names. The relationships of the soils within the fifteen river basins of the Kelani-Aruvi area to the different climatic zones and the geological origin of parent material are shown in table 4. The generalized soil map of catenas is shown in figure 23.

TABLE 4: Kelani-Aruvi Area: Soil Classification

Parent Material	Soils of the Dry zone (Catenas)	Soils of the Intermediate Zone (Catenas)	Soils of the Wet Zone (Catenas)
1. Weathered rocks of the Vijayan Series	TO - Tonigala MN - Maradanmaduwa KL - Kelegama	AD - Andigama	B - Boralu
2. Weathered rocks of the Transitional Zone	TA - Tadaratu RW - Ranorewa	MO - Maho	—
3. Weathered rocks of the Khondalite Series	ET - Etakanda AL - Aluthwewa	K - Kurunegala	B - Boralu
4. Weathered highly quartzitic rocks	MD - Medawachchiya	KW - Kiriwana	H - Homagama
5. Older transported materials	GM - Gambura WL - Wilpattu	MA - Madampe	—
6. Recent deposits	MR - Murunkan AR - Aruvi (complex)	Pu - Puttalam	NG - Negombo

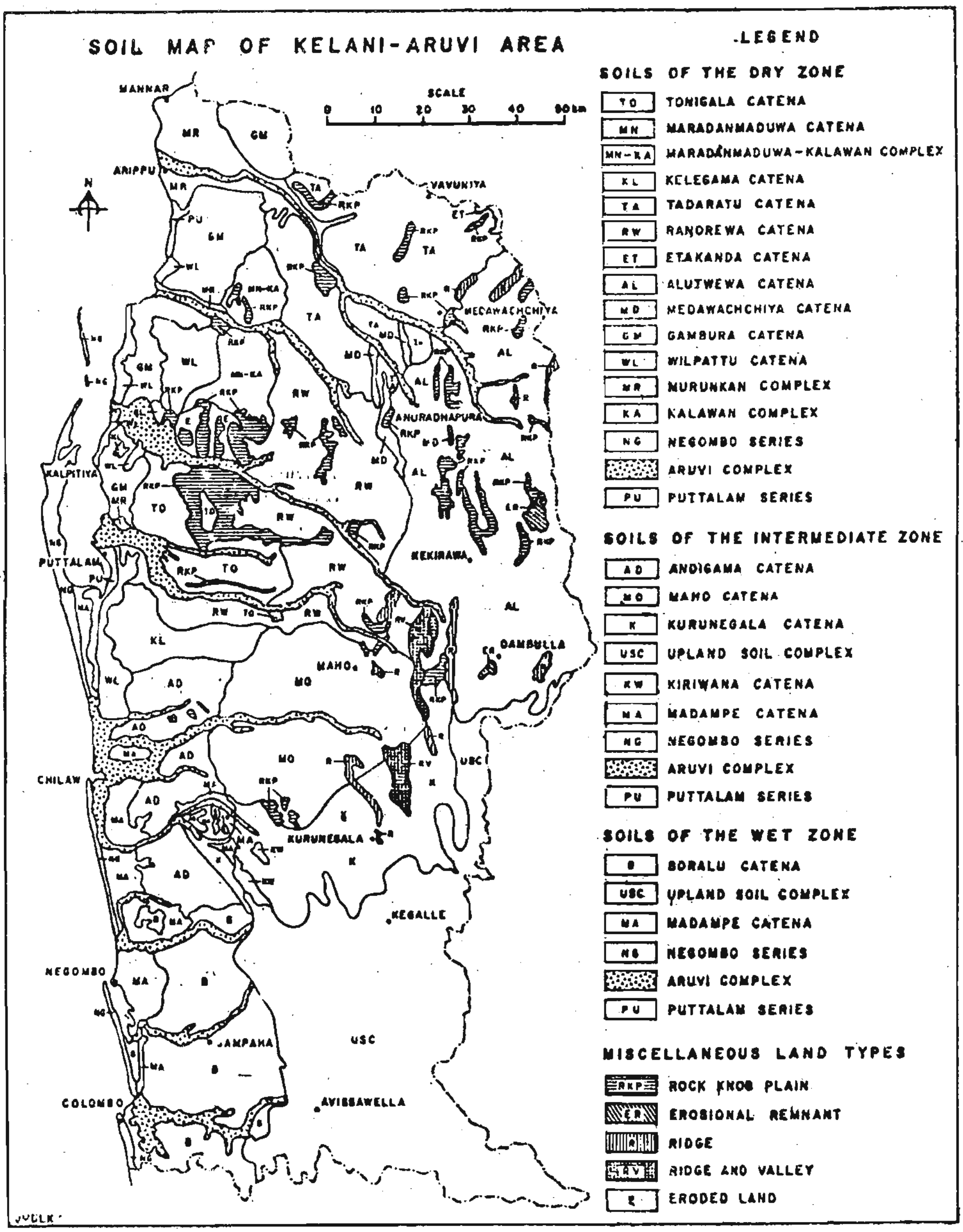

Figure 23: Soil Map of Kelani-Aruvi Area.

The study of the soils of the Kelani Aruvi area has been specially rewarding because this area provides a great variety of soil parent materials and a wide range in the annual and seasonal distribution of rainfall. Moreover, the rock type and parent material zones are oriented in belts trending generally north-south, while the rainfall zones are oriented east-west. This means that the pedologist can study climate-parent material interactions under both sets of variables. In the degree of profile development, the soils developed on residuum show some youthful features even though the parent rocks themselves are of great age.

At the closing stages of this study, when the physical and chemical analyses of the representative profiles were nearing completion, the country was fortunate in obtaining the services of the then FAO consultant, Dr F.R. Moormann. His assignment was to assist the Land Use Division in the identification and classification of the broad soil groups of the country in terms of contemporary international systems.

Reviewing and re-examining the earlier work of Joachim and co-workers, and interpreting the findings of the fifteen river basin Kelani-Aruvi study in the light of contemporary soil classification criteria, and also visiting most of the important soil and climatic zones of the island, Moormann and Panabokke presented *A New Approach to the Identification and Classification of the Most Important Soil Groups of Ceylon* (1961).

The category of generalization used in their approach was that of the *Great Soil Group* as proposed by Thorp and Smith (1949). An intermediate category of the *subgroup* was also introduced to classify soils that differ from the modal soils of the great soil group in one important feature. Recognizing and naming the great soil groups was based both on internationally employed nomenclature as well as on some great soil group names used on similar soils by Stephens (1962) for Australian soils. It was also recognized that information from further soil surveys could result in the introduction of other groups and also in the modification of the definition and nomenclature of the proposed groups.

A comparison of the earlier Joachim (1945) classification with that of Moormann and Panabokke (1961) is given in table 5.

TABLE 5: Comparison of Joachim's (1945) Classification with that of Moormann and Panabokke (1961)

1961 Classification of Moormann and Panabokke		1945 Classification of Joachim
Great Soil Group	**Subgroup**	**Major group or series**
1. Reddish Brown earths		Red to reddish brown non-lateritic loams of the dry zone
2. Noncalcic Brown soils		Non lateritic gray brown sandy loams
3. Red-Yellow Podzolic soils (modal)		Reddish to yellowish lateritic loams
	(a) Subgroup with prominent A_1	{ Wet grassland (patana) soils { Fernland *(kekilla)* soils
	(b) Subgroup with soft laterite	Red to yellowish laterite soils.
	(c) Subgroup with dark horizon	.......(not described)
4. Red-Yellow Latosols		Red and brown sandy loams
	(a) Calcic subgroup	The brick red loams *(terra-rossa)*
5. Reddish Brown Latosolic soils		Reddish to yellowish lateritic loams
6. Immature Brown loams		Immature brown loams
7. Low-humic Gley soils		Some of 'The ill-drained loams with gley subsoil'
8. Regosols (on recent sands) (on old sands)		Coastal sands (cinnamon soils)
9. Solodized Solonetz		Some of 'The shallow damana soils'
10. Grumusols		Soils similar to the black cotton soils of India
11. Bog and Half-Bog soils or Acid Swamp Soils		The low-lying peaty soils
12. Meadow Podzolic soils		Some of 'The deniya Soils'
13. Rendzina soils		The grey calcareous loams (rendzina)
14. Alluvial soils		Alluvial silts and loams Paddy soils

In determining the great soil groups of Sri Lanka on the foregoing lines, the method of diagnosis of the new taxonomic system, then termed the Seventh Approximation, was followed as closely as possible. In this system the taxonomic units are determined according to observable and, if possible, measurable properties in as much as the properties affect soil genesis or result from soil genesis. In chapter 3 of the Moormann and Panabokke publication, *Soil Classification, A Comprehensive System* (1961), the classification of the principal soils of the island according to the Seventh Approximation was also presented.

This system contains six categories. From the highest to the lowest level of generalization, these are *order, suborder, great group, subgroup, family,* and *series.* (Note the addition of the subgroup category.) In the general operating procedures of this classification system, one tends to look at the entire population of soils to the extent they are known and then place them into the ten broad groupings-the soil orders. Further subdivisions are then made within each order. There are 10 orders, 47 suborders, 330 great groups, and a larger number of subgroups, families, and series in this system. The 1975 updated version of this system is referred to as Soil Taxonomy and will be discussed in the next section of this chapter.

A parallel development that was taking place around the 1960s was the FAO/UNESCO Soil Map of the World project. It started in 1961 with the following aims:

- preparing a universal worldwide correlation of soil units
- obtaining an inventory of the world soil resources through a set of soil maps with a common legend
- providing for ready transfer of land use and management knowledge.

A bicategorical system was established (Dudal 1968) with the highest or upper class being approximately but not completely equivalent to the 'great group' level of Soil Taxonomy and some other systems, including the USSR system in vogue at that period. Panabokke (1968) presented the equivalents of the great soil groups of this country with the FAO/UNESCO legend at the presidential address to Section B of the SLAAS, and they are reproduced in table 6(a), while table 6(b) gives the legend for the Soil Map of Ceylon 1968.

TABLE 6(a): Equivalents of Sri Lanka's Great Soil Groups with FAO/UNESCO Legend

1. LUVISOLS	- **Medium to high base status soils with argillic horizon.**
Chromic Luvisols Gleyic Luvisols Orthic Luvisols	- Reddish brown earths - Low humic gley soils - Non-calcic brown soils
2. ACRISOLS	- **Highly weathered soils with argillic horizon**
Orthic Acrisols Ferric Acrisols Plinthic Acrisols Humic Acrisols	- Red Yellow podzolic soils - Red Yellow podzolic soils with mottled subsoil - Red Yellow podzolic soils with soft or hard laterite - Red Yellow podzolic soils with prominent A1 horizon/B horizon
3. FERRALSOLS	- **Soils rich in sesquioxides and having an oxic B horizon.**
Rhodic Ferralsols Xanthic Ferralsols	- Red latosols - Yellow latosols
4. NITOSOLS	- **Strongly weathered soils on basic materials at mid-to high elevations**
Eutric Nitosols	- Reddish brown latosolic soils
5. CAMBISOLS	- **Light colour, structure change due to weathering**
Eutric cambisols Dystric cambisols	- Immature brown loams (dry zone) - Immature brown loams (wet zone)
6. SOLONETZ	- **High sodium content and natric horizons**
Gleyic solonetz	- Solodized solonetz
7. PLANOSOLS	- **Soils with abrupt A-B horizon contact**
Dystric plansols	- Soils on old alluvium
8. FLUVISOLS	- **Water deposited soils with little alteration**
Eutric fluvisols Dystric fluvisols	- Alluvial soils (dry zone) - Alluvial soils (wet zone)
9. REGOSOLS	- **Soils from unconsolidated materials**
Eutric regosols Dystric regosols	- Regosols (dry zone) - Regosols (wet zone)
10. VERTISOLS	- **Self mulching, inverting soils rich in montmorillonitic clay**
Chromic vertisols	- Grumusols
11. HISTOSOLS	- Organic soils
Dystric histosols	- Bog and half-bog soils

Note: The formative elements of the names of the major soil groupings and soil units are given in appendix (I).

TABLE 6(b): Legend for Soil Map of Ceylon 1968

Soils of the Dry Zone and Semi-Dry Intermediate Zone	
1.	Reddish Brown Earths (Chromic Luvisols) & Low Humic Gley Soils (Gleyic Luvisols)
2.	Reddish Brown Earths (Chromic Luvisols) & Low Humic Gley Soils (Gleyic Luvisols); with moderate amount of gravel in profile
3.	ReddishBrown Earths (Chromic Luvisols) & Low Humic Gley Soils (Gleyic Luvisols); with high amount of gravel in profile
4.	Reddish Brown Earths (Chromic Luvisols) & Solodized Solonetz (Gleyic Solonetz)
5.	Reddish Brown Earths (Chromic Luvisols), Non-Calcic Brown Soils (Orthic Luvisols) & Low Humic Gley Soils (Gleyic Luvisols)
6.	Reddish Brown Earths (Chromic Luvisols) & Immature Brown Loams (Eutric Cambisols)
7.	Reddish Brown Earths (Chromic Luvisols) & Immature Brown Loams (Dystric Cambisols)
8.	Non-Calcic Brown Soils (Orthic Luvisols) & Low Humic Gley Soils (Gleyic Luvisols)
9.	Non-Calcic Brown Soils (Orthic Luvisols), Soils on Old Alluvium (Dystric Planosols) & Solodized Solonetz (Gleyic Solonetz)
10.	Red-Yellow Latosols (Rhodic and Xanthic Ferralsols)
11.	Calcic Red-Yellow Latosols
12.	Solodized Solonetz (Gleyic Solonetz) & Solonchaks (Ochric Solonchaks)
13.	Grumusols (Chromic Vertisols)
14.	Soils on Recent Marine Calcareous Deposits
15.	Alluvial Soils of variable texture and drainage (Fluvisols)
16.	Sandy regosols (Eutric Rhegosols)
Soils of the Wet Zone and Semi-Wet Intermediate Zone	
1.	Reddish Brown Latosolic Soils (Nitosols) & Immature Brown Loams (Ochric Cambisols)
2.	Red-Yellow Podzolic Soils (Rhodic and Orthic Acrisols)
3.	Red-Yellow Podzolic Soils (Rhodic and Orthic Acrisols) Climatic Variant
4.	Red-Yellow Podzolic Soils (Rhodic and Ferric Acrisols) with mottled subsoil
5.	Red-Yellow Podzolic Soils with Plinthite (Plinthic Acrisols)
6.	Red-Yellow Podzolic Soils with prominent A1 (Humic Acrisols/up country)
7.	Red-Yellow Podzolic Soils with dark horizon (Humic Acrisols)
8.	Red-Yellow Podzolic Soils with prominent A1 (Humic Acrisols/low country)
9.	Bog and half Bog Soils (Histosols)
10.	Regosols on old sands (Dystric Rhegosols)
11.	Alluvial soils of variable texture and drainage (Fluvisols)
12.	Regosols on recent sands (Eutric Rhegosols)

6.4 MODERN SOIL CLASSIFICATION-1970 TO PRESENT

Soil classification systems have been developed in many countries, but the majority have restricted international acceptance because they are applicable to only country-specific soil types, or are based on concepts that are difficult to apply unambiguously. Only two systems of soil classification enjoy very wide international recognition. These are Soil Taxonomy (USDA 1975) and the FAO-UNESCO Soil Map of the World (SMW) (1974).

The USDA Soil Taxonomy is a comprehensive system in that any soil profile can, in theory, be unambiguously allocated to a class in its hierarchical system at any of the six levels, from the order to the series. Soil Taxonomy can be considered an 'artificial' system in that selected soil characteristics are used to differentiate classes, although these characteristics are largely chosen to reflect agriculturally significant properties. This system, however, has some limitations in its application to the soils of the tropical regions since it was designed primarily for the classification of the soils of the United States of America.

The FAO-UNESCO Soil Map of the World (SMW) legend can be considered a truly international system that incorporates soil units used all over the world. Most soils can be accommodated within this system on the basis of their field descriptions. It is also an 'artificial' system, which borrows much from the USDA Soil Taxonomy, but it is very much simpler and the parameters chosen for class definitions are designed to reflect natural classes. Over the years, the legend of the SMW has been used as a common denominator for correlating different soil classification systems.

The CCTA Soil Map of Africa is based on the ORSTOM (French) and INEAC (Belgian) systems and can be considered a 'natural' system in which the soils are treated idealistically. It is, however, hardly used outside Africa.

On the basis of experience gained since 1974, a revised legend of the FAO-UNESCO Soil Map of the World was published in 1988 by FAO. It distinguishes 28 major soils groups, reflecting the main variations in the world's soil cover. Each of these major groups is subdivided into a number of smaller units to give a total of 153 for the world as a whole. The World Soil Resources Map (WSR) of 1991 is based on this revised 1988 legend.

In chapter 4, the placement of the country's great soil groups at the Great Group level of Soil Taxonomy and also the placement in the WSR legend were given at the end of the description for each great soil group. The formative elements of the names of the soil units which explain the etymology of the name is given in appendix (1) at the end of the text.

In the two subsequent subsections of this chapter, the underlying rationale for the placements of Sri Lanka's great soil groups within Soil Taxonomy and the World Soil Resources Map (WSR) are outlined.

6.4.1 Soil Taxonomy

The more important great soil groups of Sri Lanka can be accommodated within seven of the ten orders of Soil Taxonomy as shown in table 7. The main characterizing feature of each soil order is indicated against each name of the order in the first column of this table.

The next levels of placement at the level of the suborder and the level of the great soil group are shown in the second and third columns of this table, respectively. The equivalent great soil group of Sri Lanka is shown in the fourth column.

For further information on the key to soil orders and on the formative elements as well as the meanings of the terminology employed in respect of the suborders and great groups, the reader is referred to the original text of Soil Taxonomy (1975).

6.4.2 World Soil Resources Map (WSR) 1991

The main soils of the world have been grouped into nine sections as shown below. This grouping reflects the emphasis on common environmental factors responsible for soil forming processes and the properties of the major soil groups.

1. Organic soils: *Histosols*
2. Soils conditioned by human influence: *Anthrosols*
3. Soils conditioned by parent material: *Andosols, Arenosols, and Vertisols*

4. Soils conditioned by relief: *Fluvisols, Gleysols, Leptosols, and Regosols*
5. Soils conditioned by their limited age: *Cambisols*
6. Soils conditioned by seasonally dry or humid subtropical and tropical climate, and long evolution: *Ferralsols, Acrisols, Lixisols, Nitisols, Plinthosols,* and *Alisols.*
7. Soils conditioned by limited leaching: *Solonchaks, Solonetz, Gypsisols, and Calcisols.*
8. Soils conditioned by a steppe environment: *Chernozems, Kastanozems, Greyzems, and Phaeozems.*
9. Soils conditioned by pronounced transfer of clay or ferric-humic materials: *Luvisols, Podzoluvisols, Planosols, and Podzols.*

The placement of the great soils groups of Sri Lanka within seven of the nine groupings is shown in table 8.

It should be noted that the above represents a rational grouping rather than a true classification and should, therefore, not be confused with the classification systems discussed earlier.

The World Soil Resources Map (WSR) has been produced at a scale of 1:25,000,000 and it indicates the most common soils in a region. The value of the WSR is its synthesis of world soils which facilitates our understanding of how soils relate to climate, vegetation and the geography of continents. It encourages the use of internationally recognized names for soils rather than inexact confusing names. The WSR has also made it possible to delineate equivalent agro-ecological zones throughout the developing world, and provide a scientific basis for the transfer of experiences between areas with similar production potential.

The legend of the WSR can be used as a common denominator for correlating different soil classification systems, and it has also proved to be a valuable tool for education, research and development.

TABLE 7: Placement of Great Soil Groups within seven of the ten Orders of Soil Taxonomy

Order	Suborder	Great Group	Equivalent Great Soil Group-(Sri Lanka)
1. **Entisols** (Recently formed soils)	Aquents Fluvents Psamments	Tropaquents Tropofluvents Quartzipsamments	Alluvial soils Sandy regosols Soils on old alluvium
2. **Vertisols** (Shrinking and swelling dark clay soils)	Usterts	Pellusterts	Grumusols
3. **Inceptisols** (Embryonic soils with a few diagnostic features)	Ustrepts Tropepts	Ustropepts Eutropepts	Immature brown loams Immature brown loams - wet zone
7. **Alfisols** (order 7) (High base status forest carrying soils)	Aqualfs Ustalfs Udalfs	Tropaqualfs Natraqualfs Rhodustalfs Haplustalfs Rhodudalfs	Low humic gley soils Solodized solonetz Reddish brown earths Non-calcic brown soils R.B.E. of intermediate zone
8. **Ultisols** (order 8) (Low base status forest soils)	Udults	Tropudults Rhodudults	Reddish brown latosolic soils
		Tropudults	Red-yellow podzolic soils Red-yellow podzolic soils - mottled subsoil.
		Plinthudults	Red-yellow podzolic soils with soft laterite
	Humults	Tropohumults	Red-yellow podzolic soils with prominent A'1 horizon
	Ustults	Rhodustults	Red-yellow podzolic soils of the semi-dry intermediate zone
9. **Oxisols** (Sequioxide rich highly weathered soils of the tropical regions)	Ustox	Haplustox Eutrustox	Red-yellow latosols Calcic red yellow latosols
10. **Histosols** (Organic soils)	Hemmists	Tropohemmists	Bog and half bog soils

Table 8: Placement within Seven of the Nine Groupings of World Soil Resources Map (WSR) (1991).

Section Number	Major Grouping	World Soil Resources (WSR) Map Unit	Equivalent Great Soil Group - Sri Lanka
1	Histosols HS	Terric Histosols HSs	Bog and Half Bog soils
3	Vertisols VR	Eutric Vertisols VRe	Grumusols
	Arenosols AR	Halpic Arenosols ARh Ferralic Arenosols ARo	Regosols (Sandy) Latosols on old sands
4	Fluvisols FL	Eutric Fluvisols FLe Dystric Fluvisols FLd	Alluvial soils (dry zone) Alluvial soils (wet zone)
	Gleysols GL	Eutric Gleysols GLe Dystric Gleysols GLd	Low humic gley soils (dz) Low humic gley soils (wz)
5	Cambisols CM	Eutric Cambisols CMe Dystric Cambisols CMd	Immature brown loams (wz) Immature brown loams (dz)
6	Ferralsols FR	Rhodic Ferralsols FRr Xanthic Ferralsols FRx	Red latosols Yellow latosols
	Acrisols AC	Haplic Acrisols ACh Ferric Acrisols ACf Plinthic Acrisols ACp Humic Acrisols ACu	Red Yellow podzolic soils RYP - mottled sub soil RYP - soft laterite RYP - A1 horizon
	Lixisols LX	Haplic Lixisols LXh	Non calcic brown soils
	Nitisols NT	Rhodic Nitisols NTr	Reddish brown latosolic soils
	Plinthosols PT	Dystric Plinthosols PTd	RYP - hard laterite
	Alisols AL	Haplic Alisols ALh	Red yellow podzolic soils
7	Solonetz SN	Gleyic Solonetz SNg	Solodized solonetz
9	Luvisols LV	Chromic Luvisols LVx	Reddish brown earths
	Planosols PL	Dystric Planosols PLd	Soils on old alluvium

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CHAPTER 7

Agro-Ecological Regions of Sri Lanka

7.1 INTRODUCTION

An agro-ecological region represents a particular combination of the natural characteristics of climate, soil, and relief, which tends to find expression agriculturally in particular farming systems. Agro-ecology itself has a long and distinguished history, and the most successful practising agro-ecologists have been and are the farming communities who have learnt how to use the resources of their environment to survive, subsist, and develop their societies. We are bound to respect and learn from their understandings.

Over the last forty years, various countries have evolved their own national systems of demarcating and defining their agro-ecological regions. Better known among them are that of Emberger (1955) for Mediterranean climates, and the agro-ecological survey of Zambia (formerly Southern Rhodesia) by Vincent (1961). The latter approach, with some modifications, was adopted by Panabokke and Kannangara (1975) in the identification and demarcation of the distinctive agro-ecological regions of Sri Lanka.

The FAO agro-ecological zones project (1978) was more useful for international cooperation in agro-climatology and it used *12 major climatic divisions* for the tropics and subtropics, and the *length of growing periods* to designate class boundaries at two levels of generalization. In the full study (1981), these were combined with soil data to yield a global agro-ecological method, which again is more useful for international cooperation than for country-specific needs.

A recent example of a very functional national system is that given in *Agro-Ecological Regions of Peninsular Malaysia* by S. Nieuwolt et al. (1982), in which the delimitation of the regions is based on two sets of differences: (1) variations in the environmental requirements of different crops, and (2) regional differences in the natural environment as indicated by climate and soils.

A system of agro-ecological demarcation for Sri Lanka has been devised to meet the special requirements of research, extension, regional specialization of crops, and regional development. It has evolved from a synthesis of the more significant natural characteristics of climate, relief, and soils.

The general principles underlying the characterization and demarcation of the distinctive agro-ecological regions of the island will be outlined after a brief description of the relevant general climatic conditions in the country.

7.2 GENERAL CLIMATIC CONDITIONS

7.2.1 Rainfall

Sri Lanka occupies a unique position in the tropical world on account of the very wide range of rainfall conditions that are experienced at the zonal (wet, dry, and intermediate) level, and the striking differences that are identifiable in the annual sequential patterns of rainfall within small areas at a regional level. The island thus exhibits a very distinctive seasonality in its annual rainfall distribution. The rainfall over most parts of the island follows a well-expressed bimodal pattern. The mean annual rainfall ranges from 5,000 mm in the very wet regions to 1,250 mm in the semi-humid dry regions as seen in figure 1 (chapter 2).

While it is generally agreed that there are four rainfall seasons in Sri Lanka, the cropping seasons are two, namely, the *maha* (from October to February) and the *yala* (from April to August).

The *maha* is recognized as the major cropping season and the *yala* as the minor cropping season. The four rainfall seasons are:

Period	*Season*
◆ March to mid-May	Intermonsoon
◆ Mid-May to September	Southwest monsoon
◆ October to November	Intermonsoon
◆ December to February	Northeast monsoon

According to this seasonal categorization, both monsoons occupy a greater part of the year, namely 7.5 months or 62.5 percent of the length of the year. The intermonsoon season would be therefore 4.5 months or 37.5 percent of the year.

The southwest monsoon is of a longer duration and is also the most differentiated season in respect of rainfall. The rains during this monsoon are mainly concentrated in the southwest quadrant of the island and the season's rainfall could vary from 200 mm to more than 2,000 mm. The highest rainfall during this monsoon is experienced in the mid-elevations of the western and southwestern slopes of the highlands at an altitude of about 1,000 m. The rainfall decreases towards the higher elevations with Nuwara Eliya receiving about 1,000 mm. Dry winds and desiccating conditions are experienced in the diametrically opposite north-central, eastern, and peripheral regions of the northwest and southeast coasts.

The rainfall during the northeast monsoon varies widely, between 300 mm and 1,500 mm. The highest rainfall during this monsoon is experienced in the Knuckles range and in the lowland regions extending from this range towards the east. Lower rainfalls are recorded along western coasts from Colombo to Puttalam as well as in the Hambantota area. Apart from the Knuckles range, high rainfall is also experienced on the eastern slopes of the Namunukula and Lunugala ranges.

The intermonsoon season during March to mid-May is generally a period of unstable rainfall. These rains are chiefly of the convective type and very often occur as high intensity afternoon thunderstorms. The intermonsoon period during October-November is the more evenly balanced rainfall period in Sri Lanka. The whole island is relatively wet during this period. Except for some localized areas in the southwest slopes of the highlands, which receive a rainfall around 1,000 mm, the rest of the island on average receives 400-750 mm of rain during this season. These rains are mainly of the convective type together with those associated with depressions, and the latter is more dominant in this season. Since this is the most evenly balanced rainfall period for the whole island, the planting of crops for the major maha season is associated with the beginning of this intermonsoon period.

7.2.2 Temperature

There is only a slight annual range of temperature for the island, but this is exceeded by the diurnal range of temperature. The coastal areas have the smallest amplitude for the diurnal range of temperature while the largest range occurs in areas situated towards the interior away from the coast. The highest diurnal range of temperature is recorded during the months of February and March. In general, the diurnal range of temperature varies between 8^0C in the coastal areas to 14^0C in the central highlands.

The decrease in temperature with altitude is greater on the western than the eastern slopes of the highlands. The reason for this is the dry Kachchan winds that blow down the eastern slopes during the southwest monsoon causing a warming up of these slopes. In general, throughout the island, the warmest period is April-May and the coolest period is December-January.

Maximum temperatures are not a limiting factor for agriculture in any part of the country. However, the minimum temperature is of considerable significance for agriculture as it imposes cultivation limits on certain crops due to low temperatures during the reproductive phase. In the low country region, the minimum temperature does not fall below 20^{0}C during most of the year except in the Jaffna peninsula during December-January, which enables the cultivation of potato. In the mid-country, the average minimum temperature is in the range 17^0-18^{0}C, and the recorded minimum temperature may fall considerably lower for a few days in January-February. The implications of this for rice cultivation have been discussed by Panabokke (1980). In the up-country, the minimum temperature is in the range of 8^0-14^{0}C. The recorded minimum temperature may occasionally fall to around 0^{0}C during early February in Nuwara Eliya when frost is experienced.

7.2.3 Sunshine, Solar Radiation, and Evaporation

The duration of sunshine over the island is subject to considerable variation. The east coast and the north of the island receive the highest annual sunshine, around 2,900 sunshine hours per year. The western and southern lowlands have recorded around 2,500 sunshine hours per year. The highlands receive still less sunshine annually, around 1,600 sunshine hours per year. The western slopes of the central highlands record a lesser amount of sunshine than the eastern slopes because of the low duration of sunshine during the southwest monsoon period. The highest number of sunshine hours per day was recorded during February-March by almost all the recording stations in the island.

The average daily solar radiation for the island ranges from 300 to 500 calories per cm^2 per day. During February and early March, almost all stations record daily solar radiation values of more than 400 calories per cm^2 per day. During the month of December, almost all stations, including those in the dry zone, record daily solar radiation values of around 300 calories per cm^2 per day, or less.

There is a marked seasonal variation in class A pan evaporation (evaporation from free water surface) within the island. The highest evaporation for the wet zone is around 4 mm per day and it occurs during the months of March and September. In the dry zone, the highest evaporation of over 6 mm per day is recorded during May to September.

7.3 THE IDENTIFICATION AND DEMARCATION OF AGRO-ECOLOGICAL REGIONS (AERs)

The division of the country into two main geographical zones of the dry zone and wet zone had been widely recognized up to 1956. During the period 1956-1961, in studies conducted by the Canada-Ceylon Colombo Plan Project surveys on land use, forestry, hydro-meteorology, and soils, a transitional intermediate zone was recognized. The boundaries of these three zones, namely, *wet, intermediate* and *dry*, were demarcated after careful consideration of agricultural land use, distribution of forest species, rainfall data, topography, and soils. The delimiting criteria used for this demarcation have been described in the Forestry Inventory of Ceylon (1961).

The second stage of subdivision for agro-ecological purposes is based on elevation, which takes into account the temperature limitations for the more important plantation and arable crops grown in the country. The *low-country* is demarcated as land below an elevation of 300 meters, the *up-country* as land above 900 meters in elevation, and the *mid-country* as land between 300 and 900 meters in elevation. The dry zone falls wholly within the low-country, while the intermediate and wet zones fall within all three subdivisions.

The third stage is subdivision into the *agro-ecological* regions, which represent approximately homogeneous climatic conditions combined with the effects of soil, land form, and agricultural activities. The natural environment in each agro-ecological region can thus be generalized in terms of its distinctive rainfall probability regime, soils, and nature of the terrain.

The monthly rainfall expectancy at the 75 percent probability level was computed from available data of 381 rain gauging stations scattered throughout the island. These values were arranged and represented as annual sequential histograms from January to December. Annual sequential histograms with similar patterns were grouped together according to the agronomic significance of the resulting modal pattern. Each of these groupings could be considered equivalent to a rainfall probability regime. Matching the areas represented by these modal rainfall probability regimes against the zonal and elevation boundaries as well as against the soil map of Sri Lanka, it was possible to identify and demarcate ten agro-ecological regions for the wet zone, *nine* for the intermediate zone, and *five* for the dry zone (Panabokke and Kannnangara 1975). The demarcation of the country into its *twenty-four* agro-ecological regions is shown in the accompanying map.

The main distinguishing characteristics for each agro-ecological region in terms of the seasonality of rainfall, 75 percent expectancy value of annual rainfall, soils, and terrain are shown in the respective columns of the table accompanying map 2.

It could be observed that the differentiation of the wet zone into its distinctive agro-ecological regions is governed primarily by differences in rainfall and elevation, while for the dry zone the differentiation is governed primarily by the nature of the soils. For the intermediate zone, both rainfall and elevation as well as soils play a role in the differentiation of the agro-ecological regions.

Each agro-ecological region (AER) is denoted by two letters-cum-number. The *first letter* refers to the major zone: i.e., (W) for Wet, (I) for Intermediate, (D) for Dry. The second letter refers to the elevation: i.e., (U) for up-country, (M) for mid-country; (L) for low-country. The number that follows the two foregoing letters reflects the degree of wetness of the modal rainfall probability regime, number 1 being the highest degree of wetness and number 3 the lowest degree of wetness for each regime. This is self-evident in column four of map 2 *titled Monthly Histograms of 75 Percent Probability for Respective Regions.*

The length of the rain-fed growing season for both *maha* and *yala* seasons can be readily inferred from the patterns of these rainfall probability histograms. Of special significance is the nature of the differences in the January rainfall between the respective agro-ecological regions, and also the shifts in the peaks of the maha season rainfall from October through December between a majority of the agro-ecological regions.

A further subdivision of the larger agro-ecological regions into subregions could be made on the basis of the agronomic significance of observable differences in either the rainfall regimen zones of Sri Lanka as demarcated by Alles (1973), or else by the agricultural rainfall probability map of Sri Lanka recently prepared by Kannangara (1991). A good example of the latter is described by Kannangara (1987) for the alfisol region of Sri Lanka.

7.4 THE APPLICATION AND USE OF AERs

As indicated earlier, an agro-ecological region (AER) represents a particular combination of the natural characteristics of climate, soil, and relief, and as such each AER would support a particular farming system where a certain range of crops and farming practices finds their best expression. If one were to superpose the different kinds of farming systems on an AER map, a close match could be observed between the distribution of the different farming systems and the AER boundaries. Further detailed examination within a particular AER would reveal the range of crops and farming practices best adapted to the environmental conditions within the AER.

In some situations, the modal farming system within an AER would be primarily determined by the nature of the climate, while in others it would be determined by the nature of the soil and relief. Similarly, the range of crops and farming practices that find their best expression within an AER would also be determined both by the nature of the climate and the soil in varying degrees. Based on our present knowledge and understandings of the main characteristics of the individual AERs of this country, some illustrative examples of the best-adapted plantation, arable, orchard, and pasture crop for each AER are briefly outlined in the rest of this section. The more important climatic characteristics of each AER, chiefly rainfall, are initially elaborated in as far as these have a significant bearing on the choice of crops and cropping patterns.

7.4.1. Wet Zone

Up-Country Wet Zone WU1, WU2, and WU3

As could be observed in the monthly histograms of rainfall probability depicted in columns four and five of map 2, the above three AERs are differentiated primarily on the basis of differences in the amount and distribution pattern of the 75 percent expectancy (75 pe) of monthly rainfall. WU1 is the wettest AER with a 75 pe of 3,175 mm annual rainfall followed, in decreasing order, by WU2 with a 75 pe value of 1,900 mm, and WU3 with a 75 pe value of 1,400 mm.

In respect of the individual monthly values, it can be observed that for WU1 only the months of January and February show an expectancy value of less than 100 mm each, while all eight months from April to November show an expectancy value of more than 200 mm each, which is therefore a very wet eight-month regime. In the case of WU2, the three successive months of January, February, and March show an expectancy value of less than 100 mm each, and only the three months of June, July, and October show an expectancy value of more than 200 mm. The least wet AER, namely, WU3 has three successive months of January, February, and March with an expectancy of less than 100 mm each, and only one month, October, where the expectancy value is more than 200 mm. The peak rainfalls for WU1 and WU2 occur in the months of June and October; and for WU3 in October.

The terrain of WU3 is more subdued than that of WU1 and WU2, and the dominant soils in WU3 are the red-yellow podzolic with prominent A1 horizon. Based on the foregoing rainfall regime patterns and the nature of the terrain and soils, the agricultural potential of WU3 is ranked higher than that of WU2, which in turn is ranked higher than that of WU1.

High-grown tea is the best adapted plantation crop for WU1 on land with slopes less than 60 percent. Conservation forestry is recommended for the steep and hilly terrain. Because of the long duration of eight months of the very wet season in WU1, and thereby the low annual value of the total number of sunshine hours, the productivity of tea in WU1 is lower than in WU2. The more productive high-grown tea estates are located within WU2, especially on the rolling terrain where the soils are deeper. Because of the shorter duration of the very wet season and the higher annual value of the number of sunshine hours, the performance of tea in WU2 is superior to WU1. The steep and hilly terrain in WU2 should, however, be used for fuelwood and conservation forestry. Temperate horticulture, tree crops and vegetables are recommended in the more sheltered locations.

WU3 has most of the essential attributes for productive temperate horticulture and vegetable crops as demonstrated by the rapidly expanding extents of intensive up-country vegetable and potato cultivation. A major portion of this AER is made up of rolling and undulating plains that have a lower erosion hazard than the steep and hilly terrain. Furthermore, this AER experiences only one to two months of excessive rainfall and is thus endowed with adequate solar radiation during the essential crop growth phases. Temperate pastures also perform very well in this AER. The steep and hilly land that is found within this AER should, however, be used for conservation forestry, especially on land at over 5,000 feet elevation.

Mid-Country Wet Zone WM1, WM2 and WM3

These three AERs are also mainly differentiated on the basis of differences in the amount and distribution pattern of the 75 pe of monthly rainfall as could be observed in columns four and five of map 2. The wettest AER is WM1 with a 75 pe of 3,150 mm annual rainfall followed, in decreasing order, by WM2 with a 75 pe value of 1,400 mm, and WM3 with a 75 pe value of 1,250 mm.

It can also be observed that in the case of WM1, all eight months from April to November show an expectancy value of more than 200 mm each, which is therefore a very wet regime. In contrast WM2 and WM3 show an expectancy of between 100 mm and 150 mm from April to August with only October and November exceeding 200 mm. The peak rainfall for WM1 occurs in the months of June and October, and for WM2 and WM3 in October. While there is a close similarity between the two for the rest of the months, the intensity and duration of the dry period from mid-January to mid-April differentiate WM2 from WM3, and this has a significant bearing on the seasonality of flowering of spice and beverage tree crops. The probability of moisture stress for tree crops during February-March is slight.

The low base status red-yellow podzolic soils (acrisols) are the dominant soils of WM1, while the more productive medium base status reddish brown latosolic soils (nitisols) and immature brown loams (cambisols) are the dominant soils of WM2 and WM3. The traditional Kandyan Forest Garden Farms find their best expression in the latter two AERs because of the good quality of the soils and the ideal moisture balance resulting from the nature of the monthly rainfall distribution pattern.

The more productive tea plantations of the mid-country are found on the rolling terrain of WM1, especially in the southern province. Those in the footslopes of the western hills are less productive because of a greater soil erosion hazard. All steep and hilly land in WM1 should be under conservation forestry, and tea should be confined to land with slopes of less than 50 percent. Cardamom is recommended under light forest at higher elevations.

The upland of the agro-ecological regions of WM2 and WM3 constitute the land "par excellence" for mixed home garden tree spice crops like cloves and nutmeg and for horticulture tree crops such as avocado and durian, together with a mix of other crops such as banana, coffee, pepper, arecanut, breadfruit, jak, kitul, and yams and tubers especially of the dioscorea species. Rice in the inland valleys and terraced slopes is a traditional and sustainable form of land use in these two AERs, and rice yields are moderately high in this region.

Low-Country Wet Zone WL1, WL2, WL3 and WL4

As could be observed in columns four and five of map 2, the AER of WL1 is the wettest with a 75 pe of 2,500 mm annual rainfall followed, in decreasing order, by WL2 with a 75 pe of 1,900 mm, and WL3 and WL4 with a 75 pe value of 1,500 mm. The AERs of WL3 and WL4 are differentiated from each other primarily on the basis of differences in soils and landforms.

It can also be observed that in the case of WL1, the three months of April, May, and June together with the two months of October and November show an expectancy value of more than 200 mm each. In contrast, WL2 and WL3 show an expectancy value of more than 200 mm mainly in October. The peak rainfall for WL1 and WL3 occurs in the months of May and October; and for WL2 only in October.

As a result of these rainfall seasonality patterns, a condition of moisture deficiency is experienced in WL2 and WL4 for a short period during February-March. However, the more important limiting factor is the low amount of solar radiation or sunshine hours experienced in WL1 during the very wet five months, which adversely affects the productivity of some crops such as coconut and even rubber. Low-grown tea, however, shows a high productivity on the deeper soils but is very susceptible to drought on the shallower soils during the short dry season.

All AERs of the low country wet zone fall mainly within the category of rolling and undulating terrain, and only very small extents of hilly terrain can be found within WL1 and WL2. The erosion hazards are therefore less than in the mid-and up-country wet zones.

A greater part of WL1 is already utilized for rubber and low-grown tea plantations. A smaller part is used for mixed home garden settlements. Among the horticulture tree crops, rambuttan, mangosteen, and banana are best adapted for this environment. Rice yields in the lowland inland valleys are low to moderate.

Very productive low-grown tea plantations are found in WL2 of the Galle and Matara districts. The most suited environmental requirements for oil-palm are met in the WL2 portion of the Galle district. Coconut in a mixed home garden complex together with coffee, banana, and pepper finds its best expression in the WL2 portion of the Kegalle district. Rubber yields in the WL2 are reported to be higher than in the other AERs. Rice yields in the lowland inland valleys of WL2 are moderately high and sustainable.

Pineapple under coconut finds its best expression on the moderately gravelly soils in WL3. Coconut is grown both in pure stand and as a mixed home garden crop together with robusta coffee and banana. The yield of coconut in this environment is moderate to low because solar radiation is a limiting factor during the southwest monsoon season. Yams and tubers are grown on the less gravelly soils in the mid-slopes and lower slopes of the landscape. The productivity of the betel vine is high in this environment. Land with a high content of stone and boulder can be used for rubber. Rice yields in the lowland valley are low to moderately high and sustainable.

Crops and land use in the uplands of WL4 are very similar in almost all respects to that in WL3. The more productive cinnamon plantations of the country are mainly confined to the Galle and Matara districts of WL4. The lowlands of WL4 constitute the so-called "ill-drained lands of the low country wet zone" and the main problem paddy soils of the country are also located in these lowlands.

7.4.2 Intermediate Zone

Up-Country Intermediate Zone IU1, IU2, and IU3

The above three AERs are differentiated from each other on the basis of the differences in the amount and distribution pattern of the 75 pe of monthly rainfall, as well as differences in the nature of the terrain, as shown in columns four and six of map 2. The 75 pe of annual rainfall for IU1 is 2,150 mm, followed by IU2 with 1,400 mm, and IU3 with 1,150 mm. Since the up-country intermediate zone is located on the windward side of the northeast monsoon, it experiences the maximum rainfall during the period November to January. In the case of IU1 and IU2, the three months of November, December, and January show an expectancy value of more than 200 mm each, while in the case of IU3 it is significantly lower. The months from May to September are dry and very windy months for all three AERs because they fall within the rain shadow of the southwest monsoon. The terrain in IU1 and IU2 is more mountainous and steeply dissected than in IU3.

Most of the area within IU1 is located in and around the Knuckles massif region, which has a unique and distinctive ecology, and as such it should be preserved as far as possible in its natural state. Where development has already taken place in the past, tea is recommended on slopes of less than 50 percent, and cardamom under forest at elevations below 1,500 m. Conservation forestry is recommended for the steep and hilly terrain and for the upper watershed areas of major streams and rivers.

There is less mountainous terrain in IU2, which is mostly hilly and rolling. For such terrain, tea is recommended on slopes of less than 50 percent. Arabica coffee in sheltered locations and temperate horticulture tree crops are well suited for this environment.

The AER of IU3, which encompasses almost the whole of the so-called Uva basin has, like WU3, an ideal combination of rainfall distribution and sunshine hours for very productive temperate horticulture and vegetables crops as demonstrated by the rapidly expanding extents of up-country vegetable and potato cultivation. The rainy months of November to January are not excessively wet as in the case of IU1 and IU2, and the dry weather flow in the minor streams during May to September is generally adequate for a rice crop followed by irrigated potato and vegetables in the paddy lands. Plantation and conservation forestry are recommended on the sloping dry *patana* land and on the hilly terrain.

Mid-Country Intermediate Zone IM1, IM2, and IM3

These three AERs are differentiated from each other on the basis of differences in the amount and distribution patterns of the 75 pe of monthly rainfall, as well as on the differences in terrain, landform, and soils as shown in columns four and six of map 2. The 75 pe of annual rainfall for IM1 is 1,400 mm, followed by IM2 with 1,150 mm, and IM3 with 900 mm. In the case of IM1, the three months of November, December, and January show an expectancy value of more than 200 mm, which can be considered as excessively wet. The months from June to September are dry with moderately strong winds. The terrain in IM3 is more subdued than in the other two AERs with little or no steep terrain.

The more serious erosion hazards in the country are encountered in the steep and hilly terrain of IM1 and IM2, especially on the nonterraced slopes that are used for tobacco cultivation. Conservation and plantation forestry should therefore be given high priority for the steep and hilly terrain as well as for the catchment areas of the major reservoirs located within the mid-country intermediate zone as a whole. Tea should be confined to the higher elevations on slopes of less than 50 percent. Either arabica or robusta coffee could be grown according to elevation. Mixed home garden tree crops in more protected sites, and sugarcane and allied soil protective crops in more open sites would be the more appropriate and sustainable form of land use. On the terraced slopes and in some inland valleys, rice during the wet season and vegetable crops during the dry season is a traditional and sustainable form of land use.

The AER of IM3 is often described as the meeting point of the dry, wet, and intermediate zones in the sense that it contains the largest range and diversity of most of the tree and arable crops grown in the island. This is most evident around the Matale and the Kundasale-Wattegama areas. The reddish brown latosolic soils of high base status or the nitisols that occur within this AER constitute the best cocoa growing soils of the country. As in the case of WU3 and IU3, the combination of rainfall distribution pattern and the total number of sunshine hours in IM3 makes it an ideal environment for a wide range of tree crops. The most productive cocoa, coffee, and pepper plantations and tree spice crop gardens are found in this AER. On the paddy lands, rice during the wet season is alternated with vegetables during the dry season.

Low-Country Intermediate Zone IL1, IL2, and IL3

These three AERs are differentiated from each other on the basis of differences in monthly rainfall distribution patterns as well as differences in soils. Although the 75 pe of annual rainfall for IL2 (1,150 mm) is higher than that for IL1 (1,020 mm), the duration of the dry period for IL2 is longer and more pronounced than for IL1 during the period May to September, as could be observed in column four of map 2; hence the rationale for the placement of IL1 preceding IL2. Furthermore, the annual rainfall pattern of IL2 is almost unimodal with the main single peak in December compared to the distinctly bimodal pattern of IL1 and IL3, which have their two peaks in October and April, respectively. The distribution pattern of IL3 is very similar to that of IL1 except that the 75 pe of annual rainfall is lower (900 mm).

The dominant soils of IL1 are the red-yellow podzolic soils with mottled subsoils together with regosols on old red and yellow sands. The dominant soils of IL2 are the reddish brown earths, and those of IL3 are the noncalcic brown soils. Moisture stress is experienced in IL1 and IL2 for a short period in February-March and again in August-September, as compared to IL3 where the moisture stress period is longer and more pronounced, lasting from May to September.

The most productive coconut plantations of the so-called coconut triangle are found within IL1, which has the best combination of soils, rainfall, and sunshine hours for the high productivity of this crop. Coconut is also found as a mixed home garden crop in IL1 with interplanting of banana, coffee, and yams and tubers according to the local soil pattern. Dairy farming with both fodder and pastures is feasible close to milk-collecting points. Rice yields in the lowland inland valleys are moderately high.

Maize, sugarcane, and cassava are the more important rain-fed crops of IL2. Because of the high diurnal temperatures experienced in a greater part of this AER, the Brix sugar level of sugarcane is higher than that of other AERs. This feature could be exploited for pineapple as well. On the deeper loamy soils, citrus and mango perform moderately well in this environment. Both rain-fed and irrigated rice is grown in the lower slopes and in the valleys.

Coconut is the dominant tree crop in IL3 up to the northern limit of the Deduru Oya. Productivity of coconut declines in the drier areas north of the Deduru Oya, and cashew and mango are the more adaptable tree crops for these drier areas. Rain-fed food grain crops and tobacco can be grown during the maha season in the drier areas. Where the water supply is not limiting, high rice yields are obtained in the low-lying inland valleys.

7.4.3. Dry Zone

As could be observed in map 2, the dry zone is made up of five AERs, namely, DL1, DL2, DL3, DL4, and DL5, and they all occur in the low country dry zone. The AERs of DL1 and DL5 are differentiated from each other mainly on the basis of a difference in the amount of the 75 pe of annual rainfall rather than a difference in the monthly rainfall distribution pattern. DL1 has a 75 pe of annual rainfall amounting to 775 mm compared with DL5, which has a value of 500 mm. The other AERs of DL2, DL3, and DL4 are differentiated from each other and from

DL1 primarily on the basis of soils. The following nomenclature has been in use in the past for these five AERs.

- DL1 — Reddish brown earth region
- DL2 — Noncalcic brown soil region
- DL3 — Latosol and regosol region
- DL4 — Saline and alkali soil region
- DL5 — Very dry or semi-arid region

The foregoing nomenclature reflects the dominant great soil group of the region in the case of DL1 to DL4. In the case of DL5, it reflects the characteristic dryness of the climate. It could also be observed in column four of map 2 that the monthly rainfall distribution pattern for DL1 and DL5 is strongly bimodal, whereas for DL2, DL3, and DL4 it is almost unimodal or very weakly bimodal. This has important significance for rain-fed agriculture and also for the nature of the groundwater hydrology in the landscape.

The best-adapted crops and cropping systems for each of the five AERs of the dry zone are briefly outlined in the rest of this section.

DL1-Reddish Brown Earth Region

Rainfall variability in amount, duration, and onset of season is a pronounced feature of this region. Panabokke (1974) has discussed the application of rainfall confidence limits to rain-fed agriculture, which enables an optimum selection of planting dates and sowing-to-harvest duration of crops with a view to minimizing crop risk. Further subdivision of DL1 into five sub-regions, according to the rainfall probability map for the dry zone prepared by Kannangara (1991), enables a closer fit between the duration of the cropping season and the rainfall probability regime.

The soils in this AER occur in a catenary sequence with the well-drained reddish brown earths on the upper and mid-slopes of the undulating terrain, and the poorly drained low humic gley soils in the lower slopes and valley bottoms. More than 50 percent of the total irrigated lands of the dry zone are situated in this region, and the command areas of most irrigation schemes are predominantly low humic gley soils. Similarly, more than 60 percent of the rain-fed as well as the chena lands of the dry zone are situated on the reddish brown earths of this region. Rice is the main crop in the irrigated lowland. Coarse grains, grain legumes, oil seed, and fibre crops are the main rain-fed crops on the upland. A short season yala rain-fed crop is possible during April-May in some parts of this region.

DL 2-Noncalcic Brown Soil Region

Rainfall variability is also a pronounced feature of this region. A subdivision of DL2 into three subregions, according to the rainfall probability map of Kannangara (1991), helps to properly delineate the length of the growing season for each subregion. This region has a complex distribution of soils. Noncalcic brown soils and some reddish brown earths occur in a complex association with soils on old alluvium. The coastal strip is mainly sandy regosol.

Because of the unimodal nature of the rainfall, only a single *maha* rain-fed crop is possible in this region and it is not possible to grow *yala* rain-fed crops as in DL1. The range of rain-fed *maha* season crops is very similar to that of DL1. The productivity of both lowland and upland cropping systems is lower than that of DL1 because of the coarser texture and the highly variable depth of the soils.

On the sandy regosols of the coastal plain, which are restricted to the raised beaches, very productive coconut plantations together with some cashew plantations are present.

DL3-Latosol and Regosol Region

This AER is essentially made up of three sub-regions:

1. Shallow latosols overlying porous Miocene limestone formation
2. Deep latosols overlying massive limestone or basement rock
3. Sandy regosols.

The first sub-region is mainly confined to the northern part of the Jaffna peninsula. Shallow to moderately deep calcic red latosols overlie a very porous fossiliferous limestone substrate, which provides a stable groundwater source throughout the year. Hence the cultivation of intensive market garden crops under lift irrigation is eminently feasible and is the traditional cropping system in this sub-region.

The deep latosols that overlie massive fossiliferous limestone or the hard basement rock constitute the least exploited sub-region. Deep groundwater has been located in certain areas and these could be profitably exploited for high value crops as in Mulankavil and Killinochchi. Rain-fed cashew as a plantation crop has proved successful in the Kondachchi area.

Agricultural settlement is possible on the sandy regosols, which have an underlying Gyben-Herzburg lens of fresh water. Coconut, cashew, and mango are the main tree crops on such sandy regosols. The sand dunes and similar land with no underlying fresh water lens are best left in their natural state.

DL4-Saline and Alkali Soil Region

A greater part of this AER is made up of grumusols, solodized solonetz, solonchaks, and soils on marine calcareous sediments. Where a reliable irrigation supply is available, as under the Giant's tank in Mannar, very productive irrigated rice is grown, as in the area around Murunkan. Some rain-fed rice is grown around the borders of the several Jaffna lagoons where adequate surface leaching of salts has taken place and where good quality rainwater can be retained on bunded rice lands. The rest of the lands are of poor quality and are best suited for rough grazing and ranching of goats.

DL 5-Very Dry Semi-arid Region

The major constraint to agriculture in this region is the low effective rainfall for a greater part of the year. Effective rainfall is sufficient only during the period mid-October to mid-January for rain-fed agriculture. The effective rainfall during April-May is insufficient for yala rain-fed crops. However, one of the major opportunities in this region yet to be exploited is the command areas under the major irrigation schemes, such as the Lunugamwehera, where the physical environment is suitable for irrigated cropping for high value crops during more than ten months of the year, with proper regulation and timing of irrigation deliveries.

7.4.4. Crop Recommendations based on AERs

The characterization of the agro-ecological regions of the island has also provided the opportunity to select crops with a view to regional specialization. The publication titled Agrotechnical Information produced by the Department of Agriculture in 1990 provides information on crops most suitable for a particular AER, crops with proven economic viability under a given pricing and policy framework, sustainability in a particular environment, acceptability by the growers, and adaptability to terrain conditions.

Of special interest in this publication are the proposed cropping calendars based on rainfall distribution pattern and soil conditions of the AERs. This serves as a very good example of the application of AERs to practical needs of agriculture in a country with such a high degree of agro-ecological diversity as Sri Lanka.

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CHAPTER 8

Paddy Soils and Land Systems

8.1 INTRODUCTION

Paddy soil connotes a class of soil occurring in land that is used for growing rice and the surface of which is submerged during all or part of the growing season. Paddy soil is not a pedological term, but signifies a type of land use. According to Kawaguchi and Kyuma (1977), paddy soils occur in low-lying lands that are inundated naturally or where water can be introduced by gravity. If the water conditions are right, almost all kinds of soils can be used for rice cultivation. In Sri Lanka, the hydromorphic associates of almost all its great soil groups are used for rice cultivation. The traditional term used for the conversion of naturally occurring land to paddy fields is *asweddumizing.*

The total area of Sri Lanka's paddy lands at present is about 780,000 ha, distributed over a wide range of topographical, pedological, and hydrological conditions. These are also referred to as *asweddumized* paddy lands. Compared with other Asian rice-growing countries, Sri Lanka grows rice under a very wide range of edaphic conditions.

A little more than 75 percent of the paddy lands of Sri Lanka are located within inland valley systems of varying form and size. These inland valleys have the characteristic features of valley systems that have developed on both peneplained and block-uplifted surfaces of the Precambrian basement complex of rocks. They also exhibit a wide range of hydrological conditions based on the nature of the local rainfall and the morphology of the surrounding landscape. The distribution of paddy fields in Sri Lanka, as shown in figure 24, reveals, to some extent, the diverse nature of the various inland valley systems.

Because of landscape position, the different paddy soils of Sri Lanka are essentially either hydromorphic associates or alluvial derivatives of the great soil groups or sub-groups of the region. Most paddy soils generally reflect the chemical, physical, and mineralogical characteristics of the corresponding regional soil units shown in the general soil map of Sri Lanka.

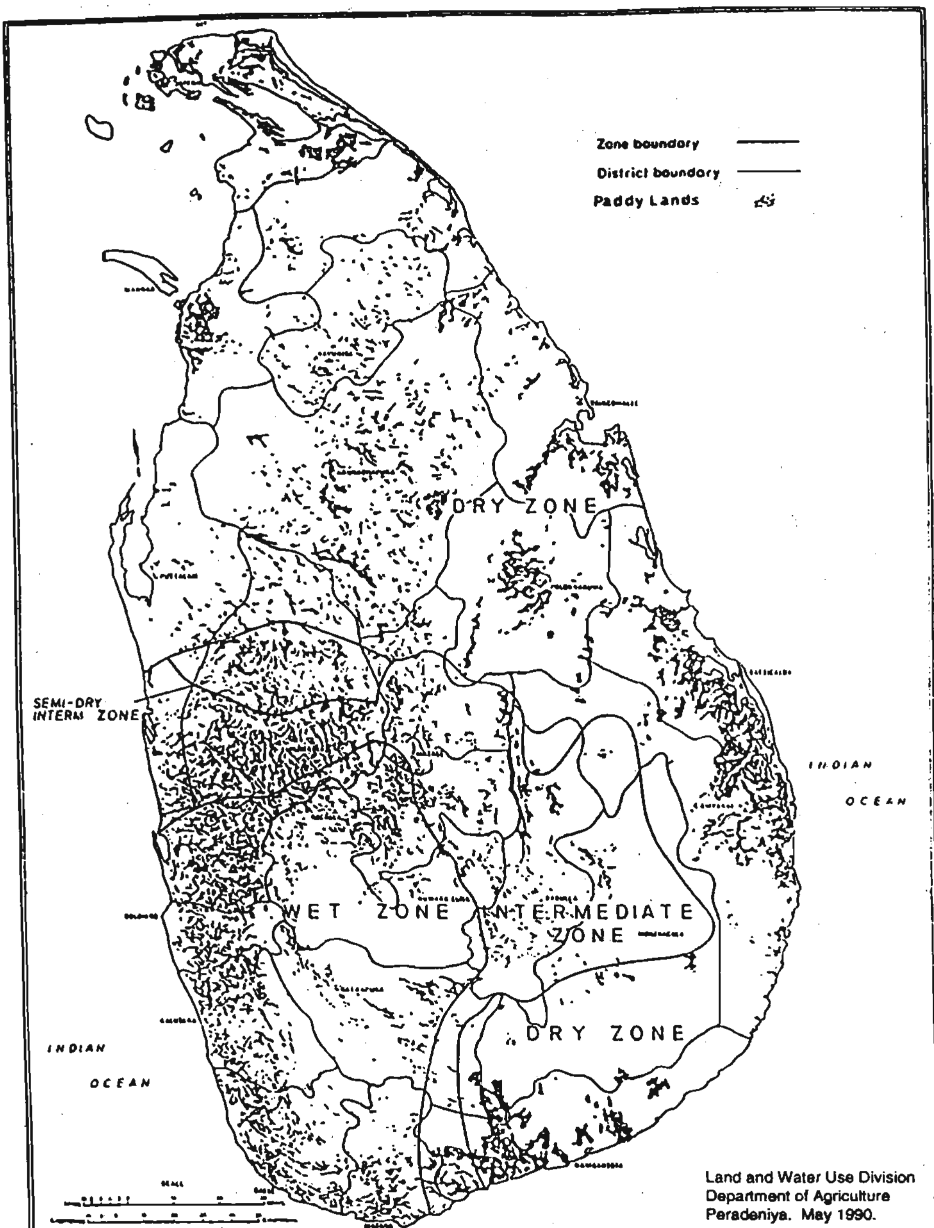

Figure 24: Distribution of Paddy Lands in Sri Lanka.

It has become evident that because of the diverse and complex environmental conditions under which paddy is grown in Sri Lanka, the paddy soils of the country are best characterized and understood with reference to:

- the morphology of the landscape in the region in which paddy is grown,
- the position of the great soil group and its hydromorphic associates in the landscape,
- the morphology and the hydrology of the inland valley system in which the paddy fields are located, and
- the variation in soil drainage within the different types of inland valleys.

Several studies of Sri Lanka's paddy soils have been reported during the past. Ponnamperuma (1959) applied the concepts of Kanno (1957), with some modifications, and proposed a classification for the mineral rice soils of the low-country wet zone. Panabokke and Nagarajah (1964) reported on the fertility characteristics of the rice-growing soils in the country. Thenabadu and Fernando (1966) described the toposequence of paddy soils in two inland valleys of the low-country wet zone. Tokutome (1970) carried out soil surveys of paddy soils in four selected sample areas of the country and proposed a scheme of classification for paddy soils of Sri Lanka based on Matsui's (1966) system.

Investigations in the mid-country districts of Kandy and Kegalle by Panabokke and Somasiri (1979) strengthened the importance of studying the whole environmental setting of the paddy lands. In addition to soil characteristics, the seasonality of the water regime or the landscape hydrology was observed to play an important role in the growth and performance of the rice crop, resulting in wide yield variations within a single paddy tract or yaya.

Typical of the mid-country paddy lands was the occurrence of three main *paddy land types* within a single *yaya* commonly described as *goda, meda,* and *mada*. Each of these paddy land types could be differentiated on drainage qualities, which in turn are well reflected in the soil profile characteristics such as mottling and gleying occurring at respective depths. The adaptability of new high-yielding rice varieties for these three paddy land types was observably different. The next step was to work out a convenient and practical approach towards identifying and characterizing the different paddy land types of the wet zone. A scheme of paddy land classification was developed by Panabokke and

Somasiri (1980) with the assistance of Dr F.R. Moormann. It included four categories, namely, *land system, land subsystem, paddy land complex* and *paddy land elements.*

Land systems are demarcated on the basis of agro-ecological regions and the recurring relief pattern. *Land sub-systems* are recognized on the basis of drainage pattern and the paddy land to upland ratio, hydrology and micro relief, and upland soil and soil parent material. The *paddy land complex* is recognized on the basis of the landform components of the individual tracts. The *paddy land elements* are identified on the basis of one or more of the following: soil drainage class, landform, slope range, and moisture distribution pattern. The overall paddy land classification scheme is given in table 9.

TABLE 9. Scheme of Paddy Land Classification

Land Category	**Determinants and Components**	
Land System	Agro-climate or agro-ecological region Overall topography and relief	
Land Subsystem	Drainage pattern and paddy/upland ratio Hydrology and micro-relief Upland soils and parent material	
Paddy Land Complex	Combination of a limited number of landforms into a contiguous tract or *yaya* *Components* include Inland Valleys and Terraced Slopes	
Paddy Land Elements	Combination of landforms, slope range, soil Elements characteristics, and moisture distribution pattern *Components* include the following:	
	Inland Valleys	*Terraced Slopes*
	Valley head	Concave slope
	Valley sides	Concave contour
	Valley bottom with incised drainage	Straight slope
		Convex slope
	Valley bottom without incised drainage	Convex contour
	Confluence of valleys	Ridge crest

Extending their studies over nine administrative districts of the wet and intermediate zones, 64 land systems were identified and demarcated by Somasiri and Ratnayake (1985). These land systems were further subdivided into land sub-systems wherever variations in land qualities were divergent enough to justify such divisions. For example, in the Kandy district, 11 land systems were identified and divided into 21 sub-systems; and in the Kegalle district 11 land systems were identified and divided into 15 sub-systems. In the Matale district, 7 land systems were identified and divided into 11 subsystems.

The paddy lands of the wet and semi-wet zones are best characterized and understood in terms of the foregoing land systems approach. Studies along these lines have been completed and published by the Land and Water Use Division of the Department of Agriculture under the title, *Wet and Semi-Wet Rice Lands in Sri Lanka* by Somasiri and Ratnayake (1988), in a limited edition. This publication is considered essential reading for a proper understanding of the paddy lands of the wet zone.

In the rest of this chapter, it is proposed to describe the more important properties of the paddy lands of the dry zone and intermediate zone based on studies carried out prior to the period 1977. This will be followed by a similar presentation in respect of the wet and semi-wet regions, which will attempt to incorporate the subsequent land systems approach. Studies conducted in paddy lands of Sri Lanka prior to 1977 have been described and discussed by Panabokke (1977) under the caption Rice Soils of Sri Lanka at the International Symposium of Rice Soils. For further information on the paddy soils of tropical Asia, readers are referred to the monograph by Kawaguchi and Kyuma (1977), and to *International Symposium: Soils and Rice; Rice Soils of the World* (1978), International Rice Research Institute (IRRI).

8.2 PADDY SOILS OF THE DRY ZONE

The paddy soils of the dry zone could be considered under three broad general categories according to the morphology of the landscape on which the soils occur:

- Paddy soils of the inland valleys
- Paddy soils of the coastal plains
- Paddy soils of minor flood-plains

Because a greater part of the paddy lands is located in the inland valleys of the lower peneplain, only the paddy soils falling with this general category are discussed, together with some management problems of the other two general categories.

The paddy soils of the inland valleys are, for the most part, confined to the moderately broad to broad, gently sloping, smooth valleys of the first and second order streams that make up the dendritic drainage pattern in an undulating catenary landscape. The side slopes of a valley are slightly concave and the gradients range from 0.5 to 1.0 percent.

The area occupied by an inland valley rarely exceeds 25 percent of the total land surface. The adjacent highland has a low relief and an undulating topography. The highland soil has an ustic moisture regime for five months of the year. During the main rainy season, there are periods when the upland profile becomes saturated with moisture. Dry season flow in the second order streams usually ceases after about 45 cumulative dry days.

The slightly incised nature of the streams and the adequate gradients of the downstream profile ensure a satisfactory surface drainage for the individual rice tracts within a valley. During the rainy season, however, the impervious, underlying, basement rocks prevent vertical drainage and the groundwater level builds up rapidly in the bottom lands and in the lower slopes. During the dry season, the water table drops at an average of 60 cm per month. The bottom lands are therefore poorly drained during a greater part of the year, while the midslopes of the valley are imperfectly drained.

This natural hydrology is, to some extent, modified by small low-head irrigation reservoirs or minor tanks located at various intervals along the valleys. In the more recent major irrigation schemes, seepage from the main canals located on the mid-aspect of the landscape considerably modifies the natural hydrology of the valleys.

The paddy soils of the inland valleys, and those of the flood plains that are not subject to flooding, constitute the most productive paddy lands of Sri Lanka. They are well adapted to the modern varieties of rice, and the greatest increases in rice yields during the past two decades were recorded on these soils.

The moderately fine-textured paddy soils of the reddish brown earth-low humic gley association have a higher yield potential than the moderately coarse-textured paddy soils of the noncalcic brown-low humic gley association. The latter association is more widespread in the eastern regions of the country. The paddy soils of the northern and eastern coastal plains have a lower yield potential because of their coarse textures, which are commonly sandy loam to loamy sand.

Only minor soil chemical problems are encountered on the soils of the reddish brown earth-low humic gley association. There are isolated spots of salinity and alkalinity and there are occasional positions of interflow salinity at the breaks of the slope in the lower aspects of the landscape.

In the drier regions of the lower coastal plain, notably in the north and northwest of the country, Natraqualfs and Salorthids have developed on marine sediments. Both salinity and alkalinity are encountered on these paddy soils, especially in the lower micro-topographical aspects of the flat landscape. Soil pH values greater than 8.5 and conductivity values of the saturated soil paste in excess of 4 mmho per cm are not uncommon.

8.3 PADDY SOILS OF THE INTERMEDIATE ZONE

The paddy soils of the intermediate zone could be considered under three broad categories according to climate, elevation, and dominant soil suborder:

- Paddy soils of the semi-wet, low country
- Paddy soils of the semi-dry, low country
- Paddy soils of the semi-dry, mid-country and up-country

Because the paddy lands of the semi-wet low country are the most extensive, only the paddy soils of this category are discussed. The paddy soils of the semi-dry low country are similar in many respects to paddy soils of the dry zone inland valley, except for their lower soil reaction and base status.

8.3.1 Paddy Soils of the Semi-Wet Low Country

The paddy lands of the semi-wet low country are usually situated within moderately broad, gently sloping valleys that occur within the first- and second-order streams in a gently undulating peneplain. The valley head and side valleys that are immediately adjacent to the residual land show a weak gradient. The adjacent highland has a low relief and a gently undulating topography.

The soil profile of the adjacent upland is moist for more than nine months of the year, and it is strongly mottled in the subsoil. Rain is the main water supply for the paddy lands. The rainwater is impounded by small traditional dikes. Seepage from the adjacent upland helps rice crops to tide over periods of intermittent drought. Where conditions permit, supplementary gravity irrigation comes from simple diversion structures that are built across the third-order streams that have an appreciable dry weather flow, or from low-head irrigation reservoirs.

Within the second-order valleys an interflow position can be observed along the main axis of the valley, in addition to the drainage toposequence down the length of the main valley. The permeability of the upper soil substrata in this region permits sufficient lateral movement of water from the adjacent residual land. Toxic levels of iron are observed during the peak of the rainy season at these interflow positions.

It is evident from the foregoing description that within a typical inland valley in this region pluvial[1], phreatic[2], and fluxial[3] categories of paddy lands can be recognized.

The typical catenary sequence in this landscape consists of red yellow podzolic soils and their drainage associates. Most of the paddy lands are located in the imperfectly drained and poorly drained members. Recent studies indicate that most of the paddy lands fall within the imperfectly drained member, which, in this region, corresponds to the low humic gleys of low-base status.

More than 75 percent of the paddy lands in the semi-wet intermediate zone are locally referred to as rain-fed paddy lands in the sense that they are almost entirely dependent on rainfall for water. Coincident with the bimodal rainfall pattern, two crops of 100 to 135 day duration can be grown in these paddy lands.

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[1] Water exclusively from rain; free drainage of profile.
[2] Water both from rain and shallow groundwater interflow; seasonal saturation.
[3] Water from all sources; saturation of profile for most of the year.

Depending on the texture of the surface soil, the permeability of the profile, and the availability of phreatic water, the reliability of the water regime for successful rice culture is quite variable within a single paddy tract in an inland valley. This is reflected in the assortment of cultural practices that have evolved within a tract to capture the best benefits of the sequential water regime throughout a crop season. Planting time and growth duration of the rice varieties are selected to ensure a minimum risk from drought and flash floods in the different parts of the tract.

8.4 PADDY SOILS OF THE WET ZONE

The paddy lands of the wet zone constitute nearly 30 percent of the country's paddy lands. They could be considered under three broad categories according to elevation and the morphology of the landscape:

- Paddy soils of the narrow inland valleys and terraced slopes, mid-country and up-country.
- Paddy soils of the inland valleys, low country
- Paddy soils of the southwest coastal plain and associated flood plains.

Within each of the above general categories, a significant range in diversity of paddy soils is observed. The nature of this diversity is best characterized and captured in the land systems approach that was discussed earlier in this chapter.

8.4.1 Paddy Soils of the Narrow Inland Valleys and Terraced Slopes-Mid Country

In the highly dissected middle peneplain, rice is grown in narrow sloping valleys as well as on terraced slopes. The main characteristics of the paddy soils of these narrow valleys have been described by Panabokke (1978). Some aspects of the geomorphology and hydrology of the landscape in which these inland valleys are located have also been briefly outlined in the same publication. Subsequent studies by Somasiri *et al.* (1985) using the land system approach have helped to further clarify our understandings of these paddy soils in a more holistic manner.

The results of studies conducted for the Kandy district could be considered a good example of the utility of the land systems approach. Somasiri and Ratnayake (1988) have identified 11 land systems and 21 sub-systems for this district. The land systems themselves could be grouped within 2 categories, namely, inland valley systems and terraced slope systems.

The distribution of the respective land systems and sub-systems in the Kandy district is shown in figure 25.

The dominant landform, mode of occurrence, hydrology, the main land elements, and the chief hazards in respect of each of the 11 land systems is given in tables 10a and 10b.

A schematic transect of the subsystems that make up one of the land systems, namely the, Udunuwara-Yatinuwara land system, is shown in figure 26.

The Udunuwara-Yatinuwara land system is characterized by ridges and valleys of low relief together with isolated hillocks, and is situated in the Udunuwara and Yatinuwara divisions of the Kandy plateau region. Five sub-systems have been identified within this land system, which are shown schematically in figure 26.

The Gangaboda sub-system represents the alluvial terraces of different ages adjoining the major Mahaweli river system. The Ganhata sub-system is made up of hill and valley landforms where the ratio of highlands to paddy land and the depth of the highland soils are favourable for storing a considerable part of the rainfall for release during dry periods. This causes very wet conditions in the paddy lands during most of the year.

In the Embekke sub-system, because of the low relief and shallow upland immature brown loam soils, there is comparatively less moisture storage in the highlands. This causes drought conditions in the paddy lands during prolonged dry weather. In the Gadaladeniya sub-systems, the ratio of highland to paddy land as well as the deeper reddish brown latosolic soils permit better storage of moisture in the highland, and incidence of drought conditions in the paddy lands is less than that in the Embekke subsystem.

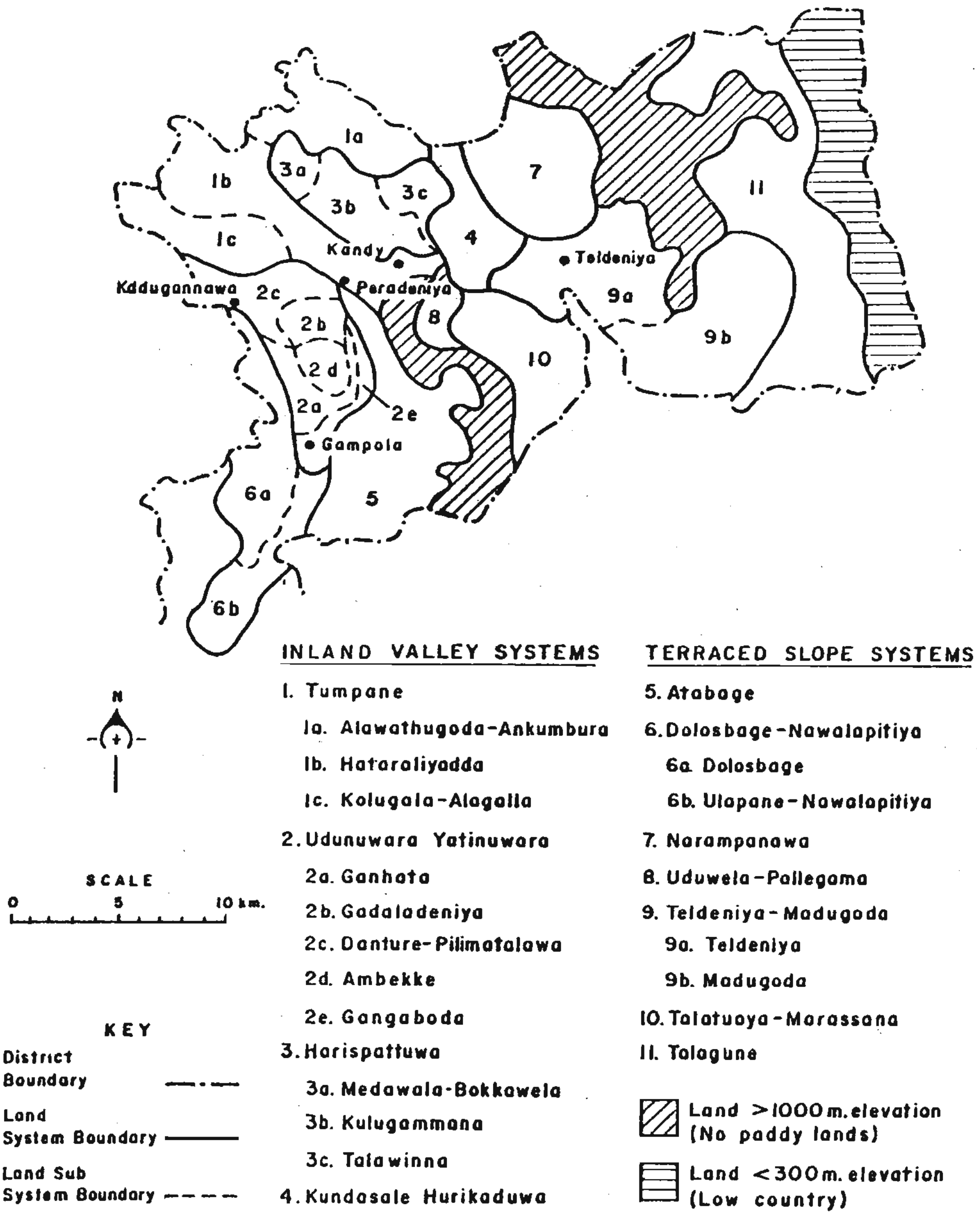


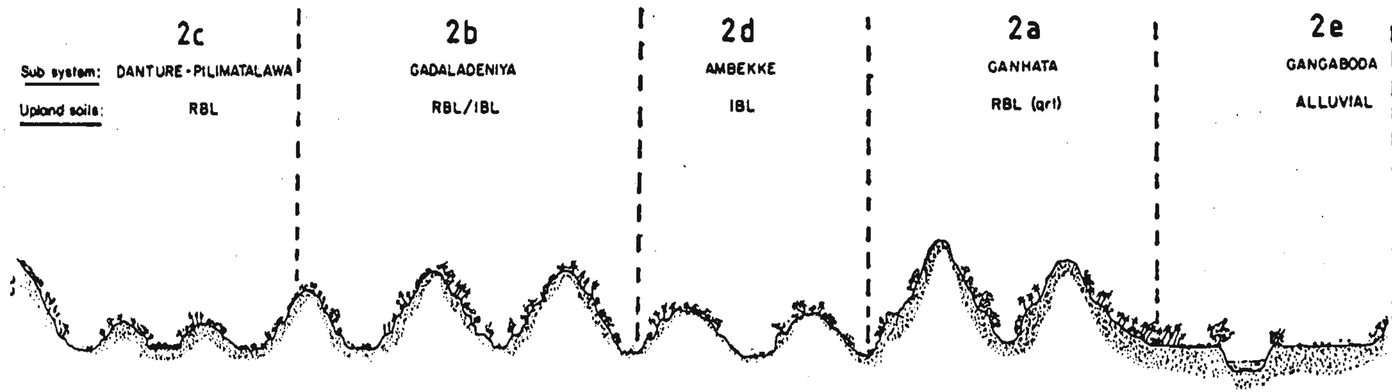
Figure 25: Land Systems and Sub-systems of Kandy District.

Table 10(a): **Land Systems of Mid-country Kandy District**
Systems with a Dominance of Inland Valley Complexes
In order of decreasing wetness

Land System	Dominant Landform	Mode of Occurrence	Hydrology	Main Land elements	Chief Hazards
1. Tumpane	Ridge, hill and valley; high relief	Long, smooth, central valleys; terraced	Rainfall Phreatic Streamfed	1. Valley floor 2. Valley sides 3. Hill slope	> Flash floods in central valley
2. Udunuwara - Yatinuwara	Rolling to hilly; moderate relief	Central valleys, side valleys, valley sides, and foothill slopes	Rainfall Phreatic Streamfed	1. Sloping central valley 2. Confluence and steps 3. Valley bottom 4. Valley side 5. Valley head 6. Foot slopes	> Flash floods in central valley > Interflow and upwelling in confluence > Drought risk in the valley sides
3. Harispattuwa	Rolling; low relief	Sloping narrow valleys, valley sides, foothill slopes	Rainfall Streamfed	1. Valley floor 2. Valley side 3. Valley head 4. Confluence and steps	> Flash floods > Drought risk
4. Kundasale - Hurikaduwa	Hill and valley; low relief	Stepped central valleys, side valleys, valley sides	Rainfall Streamfed	1. Valleys 2. Valley steps	Drought risk

Table 10(b): **Land Systems of Mid-country Kandy District**
Systems with a Dominance of Terraced Slope complexes
In order of decreasing wetness

Land System	**Dominant Landform**	**Mode of Occurrence**	**Hydrology**	**Main Land elements**	**Chief Hazards**
5. Atabage	Steep hill and narrow valleys	Narrow valleys and terraces	Rainfall Phreatic Streamfed	1. Convex slopes 2. Terraces 3. Broad valleys 4. Concave slopes	Upwelling: too much rain at harvest
6. Dolosbage - Nawalapitiya	Steeply dissected secondary plateau and escarpment	Isolated basin type valleys, narrow steep valley, hill slopes	Rainfall Phreatic Streamfed	1. Alluival-fans 2. Terraced slopes 3. Broad valleys 4. Concave slopes	Up-welling, excess rain at harvest
7. Narampanawa	Hill and valley high relief	Steep mountain slopes, sloping valleys	Rainfall Streamfed	1. Convex contour	Slumping, nutrient deficiencies
8. Uduwela - Pallegama	Warped basin enclosed by moderately high relief	Hill and mountain slopes	Rainfall Streamfed	1. Convex contours 2. Terraced slopes 3. Suspended valley steps	Drought risk Upwelling
9. Teldeniya - Hurikaduwa	Hill and valley low relief Hill and valley high relief	Sloping valleys Mountain and hill slope	Rainfall Streamfed	1. Convex slopes 2. Convex and concave slopes	Drought risk yala and early maha
10. Thalatuoya - Marassana	Secondary ridges Narrow valleys moderate relief	Hill slopes	Streamfed Rainfed	1. Convex contour 2. Concave contour 3. Valley sides 4. Valley steps in central valleys	Drought risk in yala Drought risk in early maha Yala water shortage
11. Talagune	Parallel and sub-parallel ridges and terrace valleys	Mountain and hill slopes	Streamfed Rainfed	1. Convex contour 2. Concave contour 3. Hill slopes	



RBL - Reddish brown latosolic soils
IBL - Immature brown loam

Figure 26: Transect of Sub-systems of the Udunuwara-Yatinuwara Land System. (Somasiri and Ratnayake 1988)

In the Danture-Pilimatalawa subsystem, the first order valleys and the valley steps are well supplied with water from spring flow, but the higher order valleys and valley sideslopes tend to dry up in late February and March and the paddy lands then require supplementary irrigation from stream diversions.

The foregoing hydrological characterization of the different land subsystems is only one aspect of the utility of the land systems approach. Somasiri and Ratnayake (1988) describe and discuss several other important applications of this approach.

8.4.2 Paddy Soils of the Inland Valleys-Low Country

Several kinds of inland valley systems exist in the lower peneplain of the wet zone. The more common and the more widespread of these occur in the Gampaha and Colombo districts and parts of the Kalutara district. The paddy fields are usually confined to the valleys of the second and third order streams. Panabokke (1977) has described some aspects of the hydrology and geomorphology of the landscape. Special attention has been drawn to the vesicular laterite highland adjacent to these valleys, which provides a slow discharge of surface spring flow as well as a phreatic flow of water from the aquifer held within the vesicular laterite. This augments the water supply for the rice crops in addition to the seasonal rains. It was also observed that the occurrence of iron toxicity is mainly confined to those positions in the flat valley where interflow streamlines from the adjacent landscape emerge within the valley.

The application of the land systems approach to the inland valley systems of this region has also helped to further clarify our understandings of these paddy soils and to properly identify their more important production constraints.

Somasiri and Ratnayake (1988) have identified and characterized 9 land systems for the Gampaha and Colombo districts, and 5 land systems for the Kalutara district. Figures 27 and 28 show the distribution of the respective land systems in these districts.

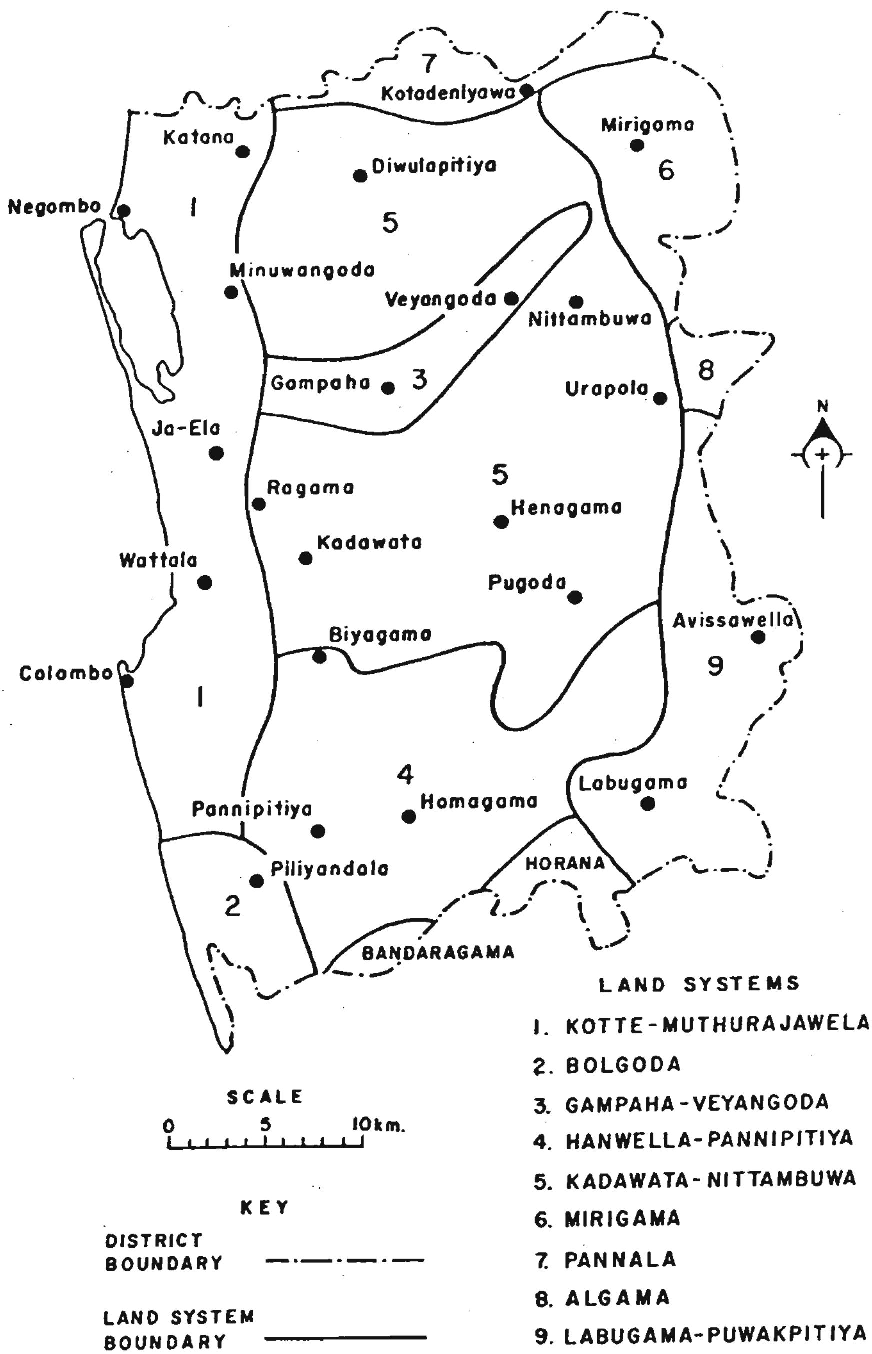


Figure 27: Land Systems of Colombo and Gampaha Districts.

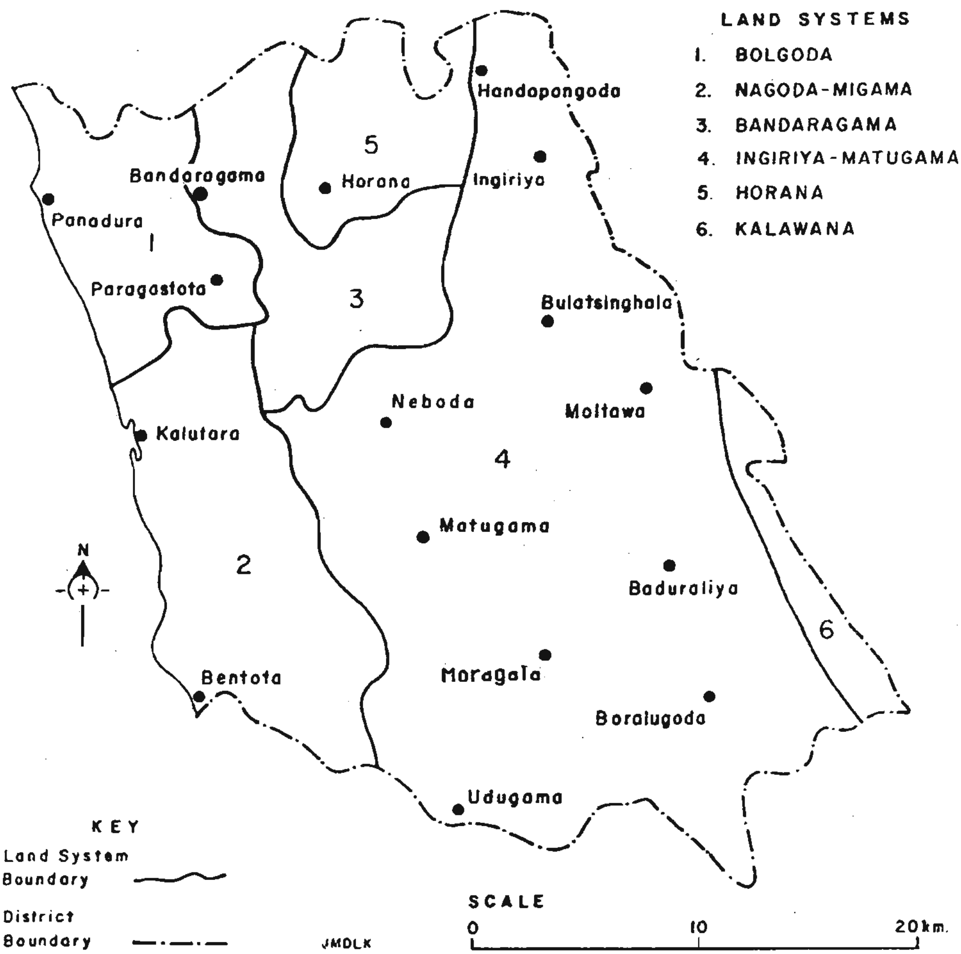


Figure 28: Land Systems of Kalutara District.

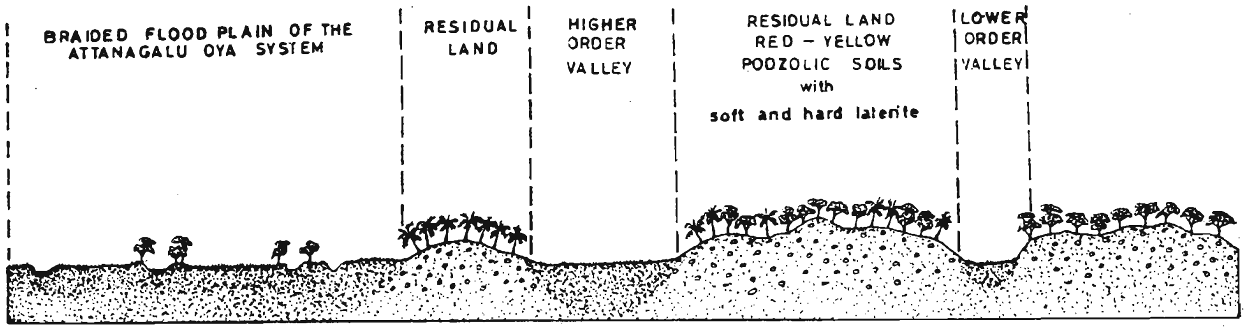


Figure 29: Schematic Transect of Gampaha - Veyangoda System (modified from Somasiri & Ratnayake 1988).

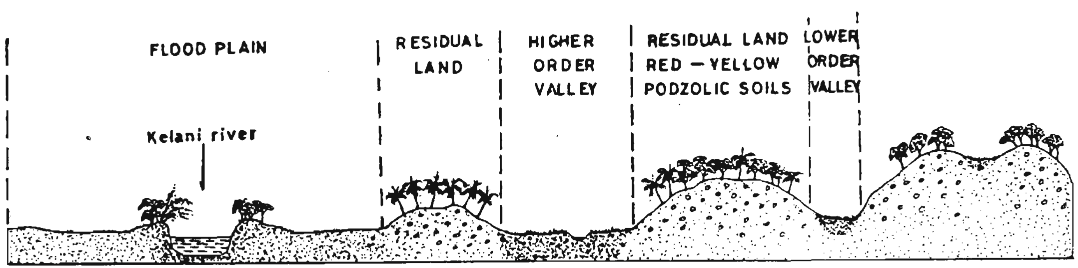


Figure 30: Schematic Transect of Hanwella - Pannipitiya System (modified from Somasiri & Ratnayake 1988)

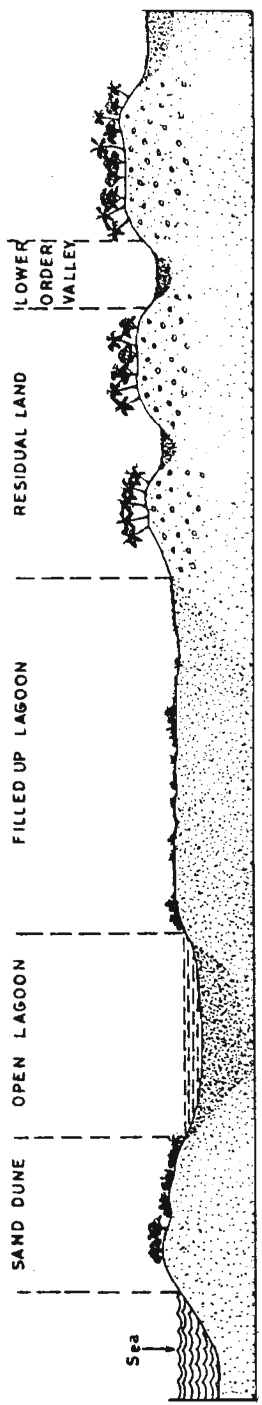


Figure 31: Schematic Transect of Kotte - Muthurajawela System (modified from Somasiri & Ratnayake 1988).

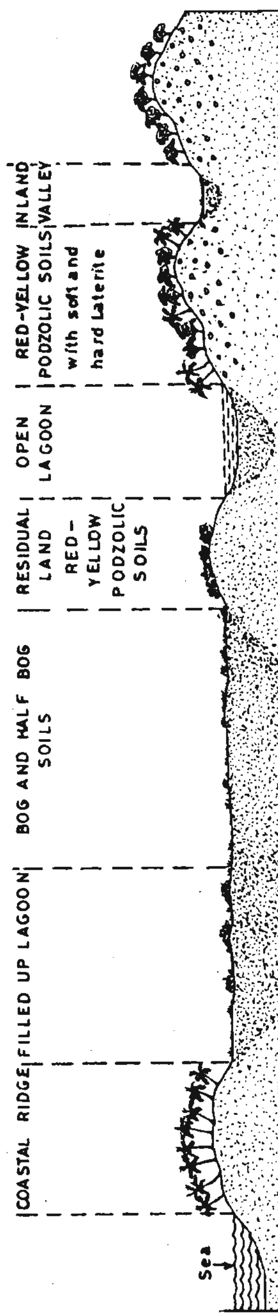


Figure 32: Schematic Transect of Bolgoda System (modified from Somasiri & Ratnayake 1988).

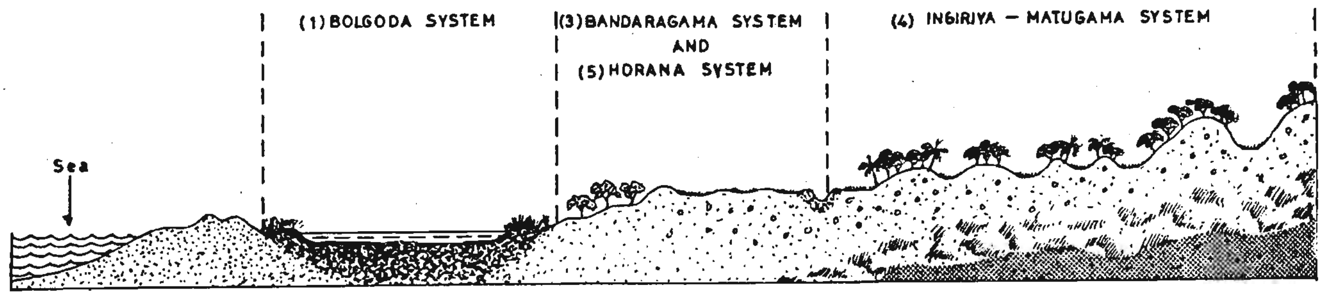


Figure 33: Schematic Transect Across Four of the Six Land Systems of the Kalutara District (modified from Jayawardena 1989).

Schematic transects of 4 of the land systems in the Colombo district are shown in figures 29 to 32. These sketches are self-explanatory and they show the positions of the filled lagoons, flood plains, and the lower and higher order inland valleys in relation to the significant landscape elements.

A schematic transect across 4 of the 6 land systems of the Kalutara district is shown in figure 33. This district provides a good example of the wide range of paddy land potential across the district. Relationship between the characteristics of the individual land systems and the paddy land potential is shown in table 11.

This exemplifies the effectiveness of the land systems approach as an analytical tool in properly diagnosing the significant constraints in the productivity of paddy lands in the low country wet zone.

8.4.3 Paddy Soils of the Southwest Coastal Plain and Associated Flood Plains

The definition, setting, and general problems of the paddy soils of the west and southwest coastal plain and associated floodplain have been described and discussed by Panabokke (1977). The principal hydromorphic soils of this region, namely, the bog soils, half-bog soils, and different kinds of alluvial soils have been described with reference to their formation, classification, and distribution by Dimantha (1977). Some of the more salient features and problems of these paddy soils are outlined here.

The nonproblem paddy lands in this region are generally those located more than 1.5 m above mean sea level, and also those located on the fairly well drained levees of streams and rivers. Locally these are referred to as the mineral paddy soils of the low-lying lands, and belong to the orders Entisol and Inceptisol.

The problem paddy lands in the region are locally referred to under the broad title of ill-drained lands of the low country wet zone. These ill-drained lands are confined to the landscape positions of filled-up lagoons, tidal marshes, back swamps of major and minor rivers, and narrow valleys of the hinterland that have constricted drainage outlets. The majority of the paddy soils of these problem lands belong to the order Histosol and suborder Hemmist.

TABLE 11: Land System Characteristics and Paddy Land Potential - Kalutara District

Land System	Relief	Highland/ Paddy land ratio	Nature of Inland Valleys	Soil Characteristics	Yield levels	Paddy land Potential
1. Bolgoda system	Flat to gently undulating low relief	Very low	Flat to slightly flat broad valleys	Poorly drained alluvial soils, bog and half bog soils	0.5 to 1.0 T/ha	Very Low
2. Bandaragama system	Gently undulating, low relief	Equal	Flat to gently sloping, medium to broad main valleys; narrow side valleys	Imperfect to poorly drained alluvial soils and half bog soils in main valleys; Coarse textured imperfectly drained soils in side valleys	1.0 to 1.5 T/ha	Medium to High
3. Horana system	Undulating to rolling low to medium relief	Equal	Gently sloping, medium to broad main valleys; narrow to medium side valleys	Imperfectly drained alluvial soils in main valleys; Coarse textured imperfectly drained soils in side valleys	2.5 to 3.5 T/ha	Very High
4. Ingiriya - Matugama system	Rolling to hilly, moderate relief	High	Gently sloping medium to broad parallel valleys	Moderatly drained alluvial soils in main valleys; Coarse textured leached sandy soils in side valleys	1.0 to 2.0 T/ha	Medium to Low

(Adopted from Jayawardena - 1988)

The more complex problems are encountered in Histosols that occur within the lagoon system of the lower coastal plain. The alluvial deposits of the short and small rivers that come down from the hinterland generally widen towards the low-lying plains closer to the sea. These deposits then form a typical marshy plain that is bounded by a sand ridge on the coast. Lagoon type lakes or ponds also form within this marshy plain. The lagoon system is made up of both the marshy plains and the lagoon type lakes.

The tidal range in the region is between 45 cm and 60 cm during spring tide and between 10 cm and 25 cm during neap tide. During dry weather, salt water intrudes into lands 50 cm or less above mean sea level and damages the rice crop, especially during the early stages of growth. Flooding during periods of heavy rainfall constitutes an equally serious hazard if a sandbar has built up at the outfall to the sea. Some of the traditional rice varieties grown in these paddy lands have some degree of tolerance to coastal salinity, and are also capable of surviving short duration flooding of 4 to 5 days.

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CHAPTER 9

Land Evaluation and Land Suitability Assessment

9.1 INTRODUCTION

One of the more important uses of soil surveys and soil survey findings in modern times is their interpretation for land use planning in the form of land capability and land suitability classifications. The main aim of such classifications is to guide planning decisions in a way that the resources of the environment are put to the most beneficial use, while at the same time conserving them for the future.

At the start itself one should recognize the distinction between soil and land. Land includes soil and other attributes such as climate, topography, hydrology, vegetation, and even socio-economic factors. The value of agro-ecological information in this regard, therefore, hardly needs emphasis.

A review of the more important land evaluation systems is contained in Young (1976) and Dent and Young (1981). In order to minimize the confusion over the use of different terminologies such as land evaluation, land capability classification, and land suitability classification, the following standard terminology is recommended.

Land evaluation: A general term embracing all forms of interpretation, and not implying any particular method of evaluation, or classification or final land use.

Land capability classification: A more specific term derived from the USDA Land Capability Classification that is used for a ranked system based on the severity of land limitations for general agricultural use (e.g., slope, erosion risk).

Land suitability classification: A term that relates to a more specific use, this being implied by the word suitability rather than capability. A specific example is the United Stated Bureau of Reclamation (USBR) land classification system, which classifies land by its suitability for irrigated agricultural development and which has been adopted by most countries for irrigation development projects. Recent national examples that will be discussed later in this chapter are: (a) the land suitability classification for tea, and (b) the land suitability classification for coconut.

9.2 EVOLUTION OF LAND EVALUATION TECHNIQUES

At a certain stage it was realized that a knowledge of soils alone would not enable a proper evaluation of land for potential uses. Other attributes of land such as climate, hydrology, present land use, in addition to human, economic and social factors are also important in evaluating land. Thus land evaluation methods, termed Land Classification Methods, came into vogue. Among the better known methods are the United States Department of Agriculture (USDA) Land Capability Classification introduced by Klingebiel and Montgomery (1966), and the Land Use Capability Classification of England by Bibby and Mackeny (1969).

These land classification methods were based on the interpretation of an entire complex of land characteristics. Lands are classified into about six to eight classes ranging from highly suitable land with no limitations, to unsuitable lands with extreme limitations for agricultural production. Some disadvantages of these methods were that the interpretations were done for general agricultural purposes rather than for specific crops.

The FAO Framework for Land Evaluation (1976a) gives a standard set of principles and concepts on which national or regional land evaluation systems can be constructed. It emphasizes, in particular, the importance of explicitly stating the intended land use and the level of management envisaged. The structure of this framework is given in table 12.

The framework structure, as shown in table 12, is compatible with other systems and also allows great flexibility. There are two orders, namely, suitable(S) and not suitable (N). Conditionally suitable land (Sc) is a phase of the order suitable, but its extent must be small with respect to the study area. Five classes, namely, highly suitable S1, moderately suitable S2, marginally suitable S3, currently not suitable N1, and permanently not suitable N2 are recognized. The definitions of these classes are shown in table 13.

Table 12: Structure of the FAO Land Suitability Classification.

		Category			
	Order	**Class**[1]		**Subclass**[2]	**Unit**[3]
	Kind of suitability	Degree(s) of (un) suitability		Kind of limitation	Management requirements or production characteristics
		S1	Highly suitable		
				S2 m	S2 e 1
S	Suitable	S2	Moderately suitable	S2 e	S2 e 2
				S2 m	S2 e 3
		S3	Marginally suitable	etc.	etc.
		etc.			
Sc	Conditionally suitable	Sc2		Sc2 m	
		etc.		etc.	
		N1	Currently not suitable	N1 m	
N	Not suitable			N1 e	
		N2	Permanently not suitable	etc.	
		etc.			

Notes:
1. The Class names shown here are those recommended for a three-class system. Upto five suitable classes are permitted.
2. The number of subclasses should be kept to the minimum necessary to distinguish land with significantly different management requirements or production potential. As few limitation symbols as possible should be used for each subclass. Note that S1 land is not divided into subclasses.
3. Units are normally for use at the farm planning level, and are often definable by differences in detail of their limitation (s).

Source: FAO (1976)

TABLE 13: FAO Recommended Land Class Definitions (for a system with three suitable classes)

Class	Designation	Definition
S1	Highly suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level
S2	Moderately suitable	Land having limitations which, in aggregate, are moderately severe for sustained application of a given use: the limitations will reduce productivity or benefits, and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
S3	Marginally suitable	Land limitations which, in aggregate, are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
N1	Currently not suitable	Land having limitations which may be surmountable in time, but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
N2	Permanently not suitable	Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

Notes:
1. In quantitative classifications, both inputs and benefits must be expressed in common measurable terms, normally economic.
2. Where additional refinement is needed, this should be done by adding classes (S4, S5) rather than by subdividing classes, since the latter procedure is reserved for subclass designation.
3. Class S1 may sometimes not appear on a map of a given area, although it may be included in the classification, if such land occurs - or is believed to occur - in other areas relevant to the study.

Source: FAO (1976)

9.3 APPLICATION OF LAND EVALUATION IN SRI LANKA

The General Soil Map of Sri Lanka (1972) and the earlier version of the Agro-Ecological Map (1976) have provided the two main sources of data for land use planning at a national level where broad policy decisions were guided.

The UNDP Master Plan for the Mahaweli Development Project was based on soil surveys and land capability classification studies. These studies were done on a scale of 1:63,360 according to a modified USBR method where 5 land capability classes are differentiated. Similar studies based on the same method but more detailed and on a larger scale of 1:50,000 to 1:25,000 have been carried out for all major irrigation development projects. Reports and accompanying maps for all these major irrigation development projects are available with the Land Use Division of the Irrigation Department.

A major contribution to the Integrated Rural Development Projects (IRDP) in recent years has been the several studies on land suitability evaluation and land use, which employed the FAO Framework for Land Evaluation, and were carried out by the Land Use Division of the Irrigation Department. These include the Matara district study by Dimantha (1980), Ratnapura district by de Alwis and Dimantha (1981), and the Nuwara Eliya district by de Alwis and Jayawardane (1981). The results of these studies are sufficient to carry out land use planning at the district level (de Alwis 1983), and also to conduct feasibility studies of selected projects.

9.4 LAND SUITABILITY CLASSIFICATION SYSTEMS FOR SRI LANKA

Standard maps depicting topography, climate, vegetation, soil, geology, hydrology, and present land use are available for most of Sri Lanka at one or more scales. These maps do not, however, give any direct information on how land will behave under particular use. Such inferences can only be made on the basis of interpretation of the properties of the land and on the results of experiments and experience gathered on similar land.

The principles of a system of land suitability classification for Sri Lanka have been proposed and clearly articulated by de Alwis (1977). The Sri Lanka Land Suitability Classification System he proposes is based on the same broad principles as the land capability classifications of the United States and Canada. As in these classifications, it is based on interpretations of soil map units along with additional data on other relevant land features and observations of behaviour under given use, and as such it is largely a holistic classification.

The rationale for using soil map units or groupings of such units as the basis for land suitability units according to de Alwis (1977) is

> *"that the soil integrates a larger number of land features than any other parameter used in characterizing land. Soil characteristics usually reflect the climate, vegetation, geology, surface hydrology, topography and biological activity and when we say that some operation has been carried out on the land most often it means that it has been carried out on the soil. Furthermore, soil mapping units frequently include other land features like slope, stoniness and rockiness as soil phases. Thus, soil map units, when combined with additional land data and observations of their behaviour under a particular use, are well suited to be the basic units of the land suitability classification."*

In the system proposed by de Alwis (1977), all land suitability classifications for different purposes are based on the following basic assumptions.

> *"Each classification is an interpretive grouping of land with respect to the potentialities and limitations for the particular use or purpose being considered."*

> *"A land suitability classification is not a land use recommendation; it is only a prediction regarding the behaviour of land under a particular use and defined management."*

> *"A high level of management for sustained use, but one that a majority of users are capable of attaining, is assumed."*

> *"The land is classified according to its current condition, not taking into account future improvements involving expensive investments (e.g., irrigation, major land levelling)."*

> *"Only physical factors contributing to or limiting the productivity or use of the land are considered in this classification. Size of holding, location, transportation facilities, availability of markets, service organizations, utilities, labour, etc. are not taken into account."*

> *"The suitability groupings are based on our current knowledge and understanding of the factors that influence the intended use."*

The Sri Lankan Land Suitability Classification system as proposed by de Alwis (1976) is a three tiered grouping. The categories in increasing degree of detail are given below.

1. Suitability Class
2. Suitability Subclass
3. Suitability Unit

The suitability class is a grouping of lands having the same degree of hazard or limitation for the use being considered.

The suitability subclass is a grouping of lands within each suitability class having the same kind or kinds of hazard and limitations for the use being considered. Each kind of limitation defining a sub-class can be present in different classes in varying degrees of intensity.

The suitability unit is the basic unit of suitability classification and provides the most detailed information on individual tracts of land.

9.4.1 Land Suitability Classification for Tea

An illustrative example of the application of the foregoing system is that developed for tea by de Alwis et al. (1980) and reproduced here in an abridged form.

The simplified land suitability classification for tea developed by de Alwis et al. (1980) has 4 suitability classes. Lands in each class have the same degree of limitation or hazard for the growth of tea, the limitation or hazard increasing progressively from Class 1 to Class 4.

Classes 1,2 and 3 are considered suitable for the growth of tea, in decreasing order, while Class 4 is considered unsuitable.

Lands are grouped into the four suitability classes according to (a) the degree of limitation imposed by certain specified limiting factors, (b) the nature of their interactions, and (c) the number of limitations, as given in table 14.

TABLE 14: Land Suitability Classes for Tea

Suitability Class	Degree of Limitation of Hazard	Suitability
1	No significant limitation or hazard	Very Suitable
2	Moderate single limitation or hazard	Suitable
3	Moderate, non-interacting or mildly interacting, dual limitations	Fairly Suitable
4	One or more severe limitations or strongly interacting, dual limitations or multiple, moderate limitations	Unsuitable

Source: (De Alwis et al. 1980)

Six kinds of limitations or hazards referred to as suitability subclasses are considered in determining the suitability of land for tea. The limitations and their coding symbols are climate (c), slope (t), rockiness (r), soil depth (d), soil group (s) and graveliness (g).

Lands with no limitation or hazard for the growth of tea are placed in Class 1. A tract of land with only one moderate limitation would be placed in Class 2 and would be designated subclass 2d, if the limitation present is the depth of soil. Lands in Class 3 can have two non-interacting or mildly interacting moderate limitations. Thus, a tract of land in Class 3 would be designated 3rs if moderate limitations of rockiness and soil type are both present. Lands in Class 4 have either one or more severe limitations. For example, 4t for land that is too steep for the successful cultivation of tea, or strongly interacting dual limitations or multiple limitations, and 4td for land in which both slope and soil depth are limiting. The criteria for deciding degree of the limitation imposed by each factor and the method of classification are further elaborated in the original text (de Alwis 1980).

Ultimately, the best evaluation of the physical suitability of land for tea under given management is done by the crop itself. The suitability is reflected in the yield. This makes it possible to assign a yield potential of tea for any class of land, under defined management. Table 15 gives the yield potentials assigned to each suitability class on the basis of data available and estimates of performance where no data are available.

TABLE 15: Yield Potentials for Tea in Different Suitability Classes According to T.R.I. Recomendations in Kg/ha/yr

Suitability Class	Up-Country	Mid-Country	Low-Country
1	>2750	>2500	>2750
2	2000-2750	1750-2500	2000-2750
3	1250-2000	1000-1750	1250 - 2000
4	<1250	<1000	<1250

Source: (De Alwis et al. 1980)

The simplified land suitability classification for tea when applied lends itself to interpretations concerning management decision making in regard to diversification, replanting, infilling, and conservation needs. It tells the manager how well he is performing and allows cost benefit evaluations of any new capital investments to be made on an estate.

9.4.2 Land Suitability Classification for Coconut

A land suitability assessment for coconut in the coconut growing areas of the Coconut Triangle has been developed by Somasiri et al. (1994) of the Coconut Research Institute (CRI). It recognizes five suitability classes, S1 to S5, and two unsuitable classes, N1 and N2.

The definitions of these individual classes as proposed by them are given below.

Suitability class S1- Highly Suitable

Lands that have no significant physical limitations to sustained coconut cultivation and will not require inputs above an acceptable level.

Suitability Class S2- Suitable to highly suitable

Lands that have minor limitations to sustained coconut cultivation that will slightly reduce productivity, and will not require inputs above an acceptable level.

Suitability Class S3- Suitable

Land that has some limitations to sustained coconut cultivation that will reduce productivity, and also require increased inputs to the extent that the overall profit is attractive but will be inferior to that from S2 lands.

Suitability Class S4- Moderately suitable

Lands that have limitations, which in aggregate are moderately severe for sustained coconut production. These limitations will reduce coconut productivity, and it would also require an increased input to the extent that the overall profit will be moderately attractive, but appreciably less than that expected from S3 lands.

Suitability Class S5 -Marginally suitable

Lands that have limitations, which in aggregate are severe for sustained coconut cultivation and reduce productivity. It will also require a higher input to the extent that the expenditure will be only marginally justified.

Unsuitable Lands N1 and N2

Unsuitable lands N1 have limitations that cannot be corrected with the present knowledge at current costs. Permanently unsuitable lands, N2, have limitations that are so severe as to produce no possibility of successful cultivation of coconut.

Soil series were mapped at a scale of 1:63,630 covering eleven 1 inch to 1 mile topo sheets that represent the Coconut Triangle. Land suitability maps at the same scale were prepared by interpretation of the soil maps superposed on the agro-ecological regions of the area.

The production potential of each class and its extent within the Coconut Triangle is given in table 16.

Table 16: Potential yield and Extent of Coconut of Each Suitability Class.

Suitability Class	Potential Yield (nuts/ha/year)	Extent (ha) (approximate)
S1	> 15,000	12,000
S2	12,500-15,000	202,000
S3	10,000-12,500	110,000
S4	5,000-10,000	166,000
S5	2,500- 5,000	78,000
N1 & N2		80,700
	Total	648,700

Source: (Somasiri et al. 1994)

In the use of land suitability maps for intercropping in coconut lands, it has to be clearly borne in mind that in contrast to coconut almost all intercrops do not have the same degree of wide adaptability to soil conditions as coconut. In most cases, the intercrops require specific soil conditions for their optimum performance. It is therefore recommended that it would be more appropriate to make use of the soil series maps of 1 inch to 1 mile scale that were made in the course of the survey for making choices for intercropping with coconut according to the recommendations made in table 12 of the publication by Somasiri et al. (1994).

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CHAPTER 10

Soil and Agriculture

10.1 INTRODUCTION

The relationship between agriculture and soil is, to a large extent, determined by soil characteristics. Many of these characteristics do not show up at the level of generalization used for the classification of soils at the great soil group level shown on the General Soil Map of Sri Lanka. Consequently, it is difficult to give a precise characterization of the agriculture and the agricultural potential for each map unit shown on the Soil Map of Sri Lanka.

One of the more important factors influencing agricultural behaviour of the land in this country, which is quite evident from the agro-ecological map and the preceding chapter, is the climate and, more particularly, the rainfall, its distribution pattern, and its variability; hence the AER map. A specific example may be found in the latosols, which are only sparsely used for agriculture in the dry zone while they support fair to very good coconut plantations in the intermediate and wet zones.

Bearing these limitations in mind, the soil map nevertheless provides broad spatial information on the relationships between soils in their environment and agriculture. A generalized subdivision could also be made between the soils of lowlands and soils of the upland, especially in the low country dry and intermediate zones and also the low country wet zone.

On the lowland soils, the land is predominately used for wetland rice cultivation. On the upland soils, which include the better drained soils, upland rain-fed crops are grown in the dry and intermediate zones, and perennial tree crops are grown in the wet zone. Some units such as soils map units 1 to 3 and 14 to 15 are mixtures or associations of both lowland and upland. In the extremely steep and very mountainous categories of land with slopes in excess of 50 percent, as in map unit no 12 and parts of map unit 13, natural forest and reserves are predominant.

The relationship between agriculture and soil at the level of the soil series is, however, more significant than that at the great soil group level. This is best explained by the results of the recently concluded land suitability assessment of the coconut growing area in the Coconut Triangle. It was conducted by the Coconut Research Institute in 1994. It has been observed that within the same agro-ecological region, the productivity of the coconut palm is closely correlated with the soil series on which it is grown. The highly productive coconut plantations occur on the Rathupasa, Madampe and Melsiripura series, while the less productive plantations occur on the Andigama, Kuliyapitiya and Boralu series all of which are located within a single agro-ecological region.

In the rest of this chapter, the agricultural use and potential of eight of the more extensive and principal great soil groups are discussed. The approximate extents and the topographic class of the land on which these major groups are located are given in table 17.

Table 17: Extent and Topographic Class of Major Soil Groups in Sri Lanka.

Soil Group	**Extent (000 ha)**			
	Flat to Undulating	*Rolling*	*Hilly*	*Total*
Reddish brown earth	1,300	210	100	1,610
Low humic gley soils	950	-	-	950
Red yellow podzolic soils	280	280	880	1,440
Alluvial soils	450	-	-	450
Red yellow latosols	320	-	-	320
Reddish brown latosolic soils and Immature brown loams	50	60	200	310
Noncalcic brown soils	150	15	-	165
Regosols (sandy)	190	-	-	190

Source: Dimantha 1984.

10.2 AGRICULTURAL USE AND POTENTIAL

Reddish Brown Earths

These are among the most important soils in the country because their extent, both exploited and non-exploited, is considerable, and also a greater proportion of these soils is located within close access to present major and minor irrigation systems as well as future proposed irrigation schemes. The widespread belief that large reserves of high quality land are available in the dry zone of this country has to be treated with caution because a high proportion of either shallow or gravelly phases of these soils are found interspersed with rock knob plains and eroded lands in the southeastern and northwestern parts of the dry zone. Shallow as well as eroded phases occur in the rolling terrain in the intermediate zone, in the *Savannah* forest region around Bibile, and around the immediate catchment of the Senanayake Samudra (Gal Oya) reservoir.

Three main types of agricultural use can be distinguished, but are not exclusive. The most dominant and extensive is *chena* or shifting cultivation, followed by small homestead gardens of settlers along roadsides and irrigation channels, and the smaller micro-settlements around open dug wells where the groundwater conditions are suitable. Because of population pressures, the chena cycle is now reduced to three to five years around the traditional small tank cascade settlements, and this results in long term land degradation.

Soil surveys conducted over the last thirty-five years have helped to adequately delineate the extent and distribution of these soils over the entire dry zone and intermediate zone landscapes. It has been recognized that the total extent of soils suitable for irrigation is very much in excess of the total area that could be economically served by conventional irrigation. This is true even after the complete exploitation of all water resources that could be made available from all proposed major storage and diversion schemes. This would naturally imply that future development of these soils would have to be considered within three broad categories of land use: (a) irrigated farming, (b) semi-irrigated farming within the traditional small tank cascade systems of the Rajarata, and (c) rain-fed farming linked to small tank systems.

Further aspects of the fertility characteristics and agricultural potential of these soils are discussed in Chapter 8 of Soils of Ceylon and Fertilizer Use (Panabokke 1967). Surface crusting is one of the main management problems of these soils, and it is one of the major constraints to further expansion of stable rain-fed agriculture on these soils.

Low Humic Gley Soils

Low humic gley soils, by definition, are hydromorphic soils and are hence predominantly used for wetland rice growing. In the dry and intermediate zones, rice is grown in the wet season with supplementary irrigation from small or big reservoirs. In the wet zone, rice is grown in both seasons making use of the bimodal seasonal rainfall and seepage or interflow from adjacent uplands.

The potential for dry season crop diversification in the dry and intermediate zones is now being exploited by making use of the limited amounts of both surface water and ground water from open dug wells.

Almost the whole of the command areas of the old and restored major and minor irrigation schemes of the dry zone are made up of low humic gley soils.

The major factors determining the agricultural productivity of these soils are the texture and mineralogical composition. Rice production on these soils varies greatly according to the availability of water, either rainfall and seepage from the adjacent upland, and the availability of irrigation supply. The more productive low humic gley soils are those that occur in association with the modal reddish brown earths in the dry zone, where irrigation supplies are not limiting and the clay mineralogy is dominated by smectite clays. Almost all irrigated lands in the north-central, northern and southern dry zones belong to this category of low humic gley soils of medium to high base status. Rice yields in excess of 4.0 T/ha are easily attainable on these soils when the irrigation supply is not limiting. The low humic gley soils associated with the noncalcic brown soils in the eastern province have a coarser texture and a lower base status, and on such soils rice yields are around 3.0 to 3.5 T/ha. The low humic gley soils of the wet zone that are associated with the red-yellow podzolic soils have a lower rice yield potential of 2.5 to 3.0 T/ha.

The potential for increased agricultural production is higher on the better quality low humic gley soils than on the poorer ones. Production can be easily improved and agriculture, especially crop diversification, can be readily intensified with better provision and management of irrigation supplies. In essence, the response to management on these soils is very good.

Red-Yellow Podzolic Soils

The agricultural potential of these soils vary greatly with their topographical situation, the parent materials on which they are found, and, more importantly, the different rainfall regimes in which they occur. A considerable proportion of the red-yellow podzolic soils of the wet and semi-wet intermediate zones are already exploited for a wide range of plantation tree crops such as tea, rubber, and coconut. A smaller proportion has been used for vegetables and orchard crops. The limited extents of land available for further exploitation occur either under steep terrain conditions or in very inaccessible mountainous areas. As such there is very little scope for further expansion of the cultivated extent on these soils. The major thrust should therefore be for increasing the productivity on the utilized areas and preserving the steep and inaccessible areas for environmental protection needs.

The red-yellow podzolic soils of the higher elevations are distributed over six agro-ecological regions. The productivity of these soils across these AERs show considerable variation, and these should be properly assessed and evaluated by appropriate land suitability studies in the same manner as those recently carried out for the coconut growing areas by the Coconut Research Institute. Such studies would undoubtedly help to determine the selective management practices for either tea or horticulture crops in these different environments. Similar studies are also recommended for the red-yellow podzolic soils of the mid-country and low-country regions.

One of the special attributes of the red-yellow podzolic soils of Sri Lanka, when compared with their counterparts in southeast Asia, is their enhanced robustness both in their physical and physico-chemical properties. Because of the specific nature of the parent materials from which the Sri Lankan soils are derived, namely, the meta-sediments of the Highland series of Precambrian rocks, these soils are well structured, less erodible, and do not fall within the group of low activity clays (LACs) in respect of their cation exchange properties. This imparts a higher soil structural stability to these soils and a better response to management. Nevertheless, they are prone to soil degradation under poor management and under high rainfall intensities.

While no major shifts are likely to take place in the present patterns of different crops being grown in these soils, major modifications and improvements in soil and water management are considered very essential for the sustainable management of the main group and subgroups of these soils.

Alluvial Soils

By far a larger part of the alluvial soils in Sri Lanka is used for growing rice. Those soils on river alluvium usually give relatively high yields, but in certain larger river valleys, no rice cultivation is possible due to damaging flash floods.

The better drained soils along the levees of rivers are commonly the site of human settlements, and fruit and garden crops are grown in them.

Agricultural quality and potential of the alluvial soils in Sri Lanka vary in accordance with a number of soil and environmental conditions. The main soil factors determining the quality of alluvial soils are texture, internal drainage, and mineralogical composition. Of the external factors affecting the quality of alluvial soils, surface water and the flooding regime are undoubtedly the most important.

In the alluvial soils of the dry zone that are not subject to flooding and are provided with reliable irrigation supplies, rice yields of 5 to 6 T/ha are attainable. In the flat alluvial plain of the lower Kirindi Oya and Walawe Ganga, which are under the command of both old and new major irrigation reservoirs, sustained rice yields of more than 6 T/ha are recorded. The high base status of these soils, their texture, drainage, and mineralogical composition rank them as the most productive rice growing soils of this country.

The alluvial soils of the low country intermediate zone occur in moderately broad to narrow valleys, and rice yields in these tracts are between 3 to 5 T/ha. Most of the alluvial soils of the wet zone that occupy the lower flood plains of larger rivers are subject to frequent flooding and are not regularly used for rice cultivation. Further inland, however, as in the case of the Attanagalu Oya irrigation system that is situated on a braided inland alluvial plain, rice yields of around 3 T/ha are harvested during a season.

Red-Yellow Latosols

A major part of the red-yellow latosols in the dry zone is, as yet, not cultivated, while those in the intermediate and semi-wet zones are under coconut, cashew, and mango. The calcic subgroup in the Jaffna peninsula is by far one of the most intensively cultivated of soils in this country. Extreme land pressure is compelling farmers to reclaim small plots of land from stony areas.

The most outstanding physical characteristic of these soils is their remarkable friability; soil consistence is friable when dry and nonsticky when wet. As a result, these soils can be worked under a wide range of moisture conditions. Even in prolonged rainy weather, these soils remain well drained and aeration remains satisfactory throughout. This condition is of particular advantage for crops that are sensitive to even short spells of poor soil aeration.

The absence of reliable water supplies in the dry zone region has, up to now, prevented any significant human settlement in a greater part of the red-yellow latosols. Where water could be made available in sufficient quantities for irrigation during the dry season, these soils would be excellent for orchard crops, especially citrus. In the absence of adequate water supplies, it would be unwise to attempt any kind of settled or intensive agriculture on these soils. Cashew has, however, proved to be a successful rain-fed tree crop around Kondachchi in the Mannar district and it could be extended to other areas as well where sufficient quantities of deep groundwater could be proved and safely extracted for human settlement needs.

On no condition should the present forest cover on these soils be clean felled and burnt as in the traditional chena system. The corridor system of strip clearing is the best adapted for these soils.

Conventional flood irrigation is not possible on these soils because of their very high infiltration rates; sprinkler or drip forms of irrigation would therefore be the more acceptable system to be employed. Because of the very poor chemical fertility of these soils, liberal applications of chemical fertilizer in combination with organic manure will be essential.

Reddish Brown Latosolic Soils and Immature Brown Loams

These two groups of soils are discussed together because they occur in such close association with each other, especially within the agro-ecological regions of WM2, WM3 and IM3. Although the dominant land use on both soils is very similar, there are contrasting differences in respect of soil depth, soil mineralogy, and soil physical properties between these two soil groups.

The reddish brown latosolic soils, which are now internationally known by the name of Nitisols (FAO-UNESO nomenclature) are known to occur mainly within the tropical environments. They are now considered as one of the most productive soils of the tropics that are used very intensively for both plantation and food crops. The reddish brown latosolic soils stand out in contrast to the immature brown loams in their greater depth, their very stable surface structure, their good structural stability throughout the profile, and their good water-holding capacity and permeability. This group of soils can support a high population density compared with the red-yellow podzolic soils. The best quality Kandyan home garden settlements of the mid-country of Sri Lanka are found on these soils. Similarly, the best quality cocoa plantations are found within this soil group in the intermediate zone.

Almost the total extent of these soils is already under settled agriculture, so that any further utilization has to be based on more intensive agriculture use with the aid of fertilizer. Simple terracing has been applied on these soils to some degree, but further anti-erosion measures are needed on the steeper slopes.

As mentioned previously, the present land use of the immature brown loams is very similar to that of the reddish brown latosolic soils. Although their water retention is poorer than that of the reddish brown latosolic soils, they are better supplied in weatherable minerals and base nutrients. Where they have satisfactory depth and texture, they can be as productive as the reddish brown latosolic soils. Increased production on these soils should be based on improving their moisture retention properties.

Noncalcic Brown Soils

The better quality noncalcic brown soils are derived from the Vijayan complex of gneisses, which have a limited number of minerals and are distributed around Maho-Wariyapola. These soils have a higher agricultural potential than the coarser textured soils of this group that are derived from the Bintenne gneisses of the eastern dry zone region.

The noncalcic brown soils of the Ampara-Batticaloa region are generally shallow, coarse textured, and moderately well drained, and their physical fertility is accordingly fairly poor. The water economy of these soils is poor; they dry out quickly and a drought of two or more weeks during the rainy season may seriously affect crops. The fallow period for shifting or chena cultivation is longer on these soils than on the reddish brown earths. The surface structure deterioration and micro-erosion of the plough layer are also very rapid, and the phenomenon of "shifting" is quite obvious on these soils even after one or two years of cultivation. The eroded and shallow phases of the noncalcic brown soils that occur very extensively in the catchment areas of the Gal Oya (Senanayake Samudra) reservoir have a very poor agricultural potential; long term reforestation and systematic soil conservation measures should receive special emphasis in such areas.

The noncalcic brown soils that occur around the Maho region are moderately deep, moderately coarse textured, and moderately well drained; they have better physical properties than the coarser textured noncalcic brown soils and are also less erodible. The Maho and Wariyapola soils series, which occur in the intermediate zone of the Kurunegala district and are shown in the recent soil map of the Coconut Triangle by the Coconut Research Institute (1994) could be considered the modal representatives of these better quality noncalcic brown soils.

Regosols (Sandy)

The sandy regosols that are located on the elevated beach plains with a flat topography in the Batticaloa and Puttalam districts have supported very productive coconut plantations over a long period. Despite the dry environment that prevails in these regions, the underlying fresh water supplies found on these lands within a shallow depth have permitted viable coconut plantations as well as sustained human settlement.

A new trend observed in the Kalpitiya peninsula has been the intensive cultivation of seasonal high value crops such as chilli, onion, vegetables, and potato under lift irrigation from shallow wells. Recent investigations in the Kalpitiya peninsula have highlighted the need for controlled use of this limited shallow water supply, because of the adverse environmental effects of both chemical contamination and overexploitation of the underlying Gyben-Herzberg lens of fresh water.

The sandy regosols developed on old sands, which extend from Chilaw southwards, support very productive coconut plantations. Drainage is defective in locations where an impervious layer of clay or ferruginous material occurs at a depth of 1.5 to 2.0 m from the surface. Drains have to be cut through this layer in order to provide adequate disposal of excess water that would otherwise depress coconut yields.

The dune sands that are located on the seaward side of the beach plains are best left in their natural state, except perhaps for some limited amount of reforestation with *Casuarina* species. Use for recreational purposes and tourist resorts of the coastal regosols has been sharply on the increase in the recent decades, especially those in the southwest of the country.

There is very little scope for further expansion of any kind of agriculture on the presently uncultivated extents of land on these sandy regosols. The present land use pattern in Mannar island up to Talaimannar represents a good example of the limits of expansion possible.

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CHAPTER 11

Sustainable Management of Soil and Land Resources

11.1 INTRODUCTION AND DEFINITIONS

It is very surprising how rapidly the term *sustainability* has entered the vocabulary of environmental and resource management literature. It has almost become an essential key word at every international conference and national workshop or seminar. But sustainability is not that easily grasped and it is not the type of goal, which once achieved, we could afford to sit back and relax.

Many definitions of what constitutes sustainability have been published, and definitions of sustainable agriculture are equally plentiful. The plethora of definitions implies that there are several concepts of what constitutes sustainability. By far the largest use is for agricultural and forestry purposes. The broad requirements for sustainability in as far as soil and land management are concerned could be stated in the following terms.

Sustainability:

1. Should produce sufficient food, fibre, and fuelwood for the needs of the population
2. Should be able to maintain production at the same level in any cycle of the production system
3. Should not release into the environment any products that adversely affect human occupation and cannot be easily removed from the environment

The most concise and acceptable definition of sustainable land management is that proposed by Greenland (1994), which states: *"A sustainable land management system is one that does not degrade the soil or significantly contaminate the environment, while providing necessary support to human life."*

11.2 SUSTAINABLE LAND USE SYSTEMS

At the outset, it should be recognized that existing land use systems and practices reflect the combined results of: (a) several complex interactions between internal and external forces, (b) physical and biological processes that are conditioned by human attitudes and values, and (c) the prevailing economic environment. At the same time, hardly any of the current land use or farming systems are in a stable state of equilibrium because they all require some external inputs in order to maintain their productivity. Economic factors such as providing subsidies can also have a major impact on land use practices. For a land use system or a farming system to be sustainable, it must provide the land owner with a reasonable quality and standard of living and rewards for his efforts. In the final analysis, it is the impact that all the foregoing factors have on soil stability, soil fertility, and water resources that determines the physical sustainability of any system.

It is now recognized that any sustainable land use system should meet the following broad tests.

- maintain soil pH and physical structure
- ensure a constant level of soil organic matter
- replenish soil nutrients that are removed
- avoid build up of toxic contaminants
- maintain a desirable level of flora and fauna

11.3 SOME BASIC CONSIDERATIONS

Modern soil science has advanced to a stage that enables us to establish the basic criteria that could indicate whether a particular land management system is degrading the land or not. These criteria relate to the maintenance and improvement of the physical, chemical, and biological conditions of the soil. At the same time, it should be recognized that different kinds of soils react in different manners to the same soil management practice. This differential behaviour of soils could be expressed in terms of a *robustness, fragility,* and *resilience* of a particular soil or soilscape.

Although it is not yet possible to fully quantify all the above soil attributes, a sufficient body of knowledge has been developed over the last three decades that would enable us to qualitatively characterize the nature of the robustness and fragility of some of the more important soilscapes of Sri Lanka. While robustness and fragility are terms that are self-explanatory, resilience has a broader connotation.

Resilience could be defined as the capacity of a system, either a soil landscape or a farming system, to return to its original equilibrium after a major disturbance. In the context of a developing country situation, resilience could be defined as the capacity of an agro-eco-system to return to a sustained growth of productivity rather than to its original equilibrium after a major disturbance. The concept of resilience relates to either the performance or to the state of structure of the system. While performance is measured by the yield or some other related attribute, structure relates to the pedological composition of the soil profile. Under Sri Lankan conditions, more attention should be given to performance resilience since this has an immediate socio-economic impact.

In respect of robustness and fragility, the following determinants operating either individually or interactively govern the degree of robustness or fragility of a soil landscape: (a) land form, (b) soil pedon, (c) rainfall, (d) hydrology, and (e) vegetation. The "state of the art" of our understandings in respect of each of these determinants is briefly described next.

Landforms can be characterized both in terms of their morphology and the degree of slope, both of which have a bearing on the erodibility of the landscape. Characterization of different kinds of landforms for pedological purposes has reached a very advanced state in this country. Noteworthy studies reported are those of the Photographic Survey Corporation (1959), Dimantha (1984), and Somasiri *et al.* (1988).

Studies on the structural stability and erodibility of the different soil pedons of Sri Lanka has advanced to a stage that a quantitative characterization is now possible. Noteworthy studies reported are those of Panabokke (1977), Joshua (1984), Krishnarajah (1984), and Mapa (1991). It comes through very clearly in all these studies that the alfisols are more erodible than the ultisols. In the reddish brown earths (alfisols), the erosion hazard is more pronounced on account of: (a) low water stability of soil aggregates, (b) easy slaking of the soil macro-aggregates following sudden wetting thus giving rise to surface crusting, and (c) rainfall intensities often exceeding the infiltration rates of the soils resulting in enhanced surface erosion. By contrast, the reddish brown latosolic soils (ultisols) have a high structural stability. They are followed by the various red-yellow podzolic soils. It should also be noted that the buffering capacity of and this confers a high degree of physico-chemical resilience on the various ultisols of this country.

The nature of the rainfall in different regions of the country both in terms of its seasonality, intensity, and erosivity has been studied in considerable detail by several researchers over the last 30 years. The mean annual rainfall and the erodibility of rainfall at different elevations for selected tea growing areas in Sri Lanka (Krishnarajah 1984) are shown in table 18 (Source: Joshua 1977).

TABLE 18: Mean Annual Rainfall, Erosivity and Elevation for Selected Areas in Sri Lanka

Station	Mean Annual Rainfall (mm) >25mm/hr	Erosive Rain (percentage)	Elevation Meters	Mean Annual Erosivity KE>1(R) ft.tons/acre
Ratnapura	3200	56	40	706×10^2
Galle	2275	62	21	561×10^2
Katugastota	1975	47	457	361×10^2
Badulla	1825	27	677	195×10^2
Nuwara Eliya	1725	4	1881	27×10^2

Adopted from Krishnaraja (1984)

It should be noted that the intensity of precipitation decreases with increasing elevation or altitude, and that the mean annual erosivity of rainfall at elevations of the up-country are comparatively very low.

The term "landscape hydrology" has been used by Panabokke (1992) to characterize the hydrology of water table behaviour within the landscape. This has an important bearing on soil and water management in the catenary landscapes of the dry zone both under rain-fed and irrigated conditions.

The role of vegetation cover, including its ability to recover quickly, in minimizing erosion hazards has been recognized over many years. It has been demonstrated that vegetation cover, land shaping, residue management, and proper tillage methods could be very successfully manipulated to minimize soil erosion under different farming systems both in the wet and dry zones of this country. Quantitative data in respect of soil loss under different vegetation covers as reported by Krishnaraja (1984) is given in table 19.

TABLE 19: Soil Loss Measured Under Different Vegetative Cover Management

Region	Cover/Management	Soil Loss MT/ha
Mid-country	Old seedling tea with no conservation	40.0
	Well managed clonal tea on contour	0.24
	Mixed home garden with heavy canopy	0.05
Up-country	Bare, clean weeded one year old tea	52.6
	One year old clonal tea with grass mulch	0.07

Adopted from Krishnaraja (1984)

11.4 ROBUSTNESS, FRAGILITY, AND SUSTAINABLE MANAGEMENT OF SOIL AND LAND RESOURCES

Most of the various soilscapes that have been identified in this country are usually found to occur within a particular agro-ecological region. The best example is the reddish brown earth-low humic gley soilscape that is mainly confined to the agro-ecological region of DL1. Some soilscapes, however, could cut across one or more AERs as, for example, the reddish brown earth-solodized solonetz soil scape and the laterite landscape.

The paddy lands of Sri Lanka are located within inland valleys that are spread across almost all AERs of the island. For purposes of discussing sustainable management, all paddy lands could be conveniently taken under a single category of paddy soils.

The robustness and fragility of seven of the more important and wide-spread soilscapes of the country together with the wet paddy lands are discussed in this section. By an interpretation of the presently available set of data in respect of the different determinants that were discussed in the previous section, one could recognize the following four broad classes in the continuum from robustness to fragility.

Class	***Descriptor***
1	Very robust VR
2	Moderately robust MR
3	Moderately fragile MF
4	Fragile F

The grouping of these seven soilscapes and the paddy lands is shown below.

A	***Very Robust VR***	***Agro-Ecological Region (AER)***
1.	Wet and semi-wet paddy soils	Spread across all AERs
2.	RYP* with soft or hard laterite or laterite landscape	Mainly confined to WL3 and WL4
B.	***Moderately Robust MR***	
3.	Reddish brown latosolic or Nitisol landscape	Mainly confined to WM2 and WM3
4.	RYP with strongly mottled subsoil	Mainly confined to IL1
5.	Red yellow latosols and sandy regosols or latosol-regosol landscape	Mainly confined to DL3
C.	***Moderately Fragile MF***	
6.	Reddish brown earth landscape	Mainly confined to DL1
D.	***Fragile F***	
7.	Noncalcic brown soil landscape	Mainly confined to DL2
8.	Reddish brown earth-immature brown loam landscape.	Mainly confined to IM1 and IM2

* RYP = Red Yellow Podzolic soil.

Approaches to sustainable management of each of these soil landscapes are briefly discussed in the rest of the section.

1. Wet and Semi-Wet Paddy Soils

The paddy lands or the paddy soils could be considered the most precious natural resource of this country for several valid reasons. They occupy nearly ten percent of the total surface area of the country and are distributed over all AERs as seen in figure 24 in chapter 8. They are invariably located in the lowland position of the inland valleys, except for a small area found on the terraced slopes of the mid-country. Because of this particular position they serve as efficient "sinks" for the land systems within which they are located. Furthermore, because of the alternate flooding and drying that they experience during the cropping season as well as between the seasons, soil reducing conditions alternate with oxidizing conditions. This regular alteration of soil reducing and oxidizing conditions contributes very significantly towards deactivating various forms of pollutants that get translocated into the valley bottoms. Where the natural drainage system is sufficiently incised, these pollutants are readily flushed out of the system.

Long term quantitative data are now available to reinforce the assertion that the paddy-paddy cropping patterns normally practised on these soils constitute one of the most stable and sustainable management systems in this country. A benchmark survey on the fertility characteristics of the rice growing soils of Sri Lanka conducted by Panabokke and Nagarajah (1964) provided an important baseline situation. Studies conducted almost thirty years later under the FAO fertilizer program in the Nutrient Management of Lowland Rice and reported by Rezania et al. (1992) conclude that *"the rice-rice cropping pattern of the low country dry zone and mid-country wet zone can be considered a natural system with little complexity and low input requirement. Sustainability and improvement of this healthy system is not difficult."* Improvement and maintenance of the organic matter content of the dry zone paddy soils require special attention. Sustainability could be achieved by application of green manure, recycling rice straw, and applying available quantities of organic material to cash crops during the dry season.

Amarasiri (1990) reports on the build up of toxic levels of heavy metals and phosphorus in the paddy soils of the up-country intermediate zone around Welimada where, in the rice-vegetable-potato cropping system, large quantities of cattle manure and phosphate fertilizer have been in use over the last 25 years.

In the major irrigation systems of DL5, salinity build up is being recorded in locations where the natural drainage system is malfunctional. Preliminary studies in the DL1 region indicate the inducement of adverse reducing conditions in the bottom lands in the Mahaweli diversion area consequent to prolonged submergence in the blocked drainage ways.

In summary, it could be stated that the paddy soils of this country constitute a very robust and resilient land resource that should be carefully managed and nurtured in order to ensure long term sustainability. The priority problems of the paddy lands have been properly diagnosed and corrective measures should be supported even with modest state subsidies.

2. *Laterite Landscape*

The highest population density in the country is observed within this soil landscape. However, because of the robustness and high resilience of the laterite upland, there are as yet no significant indications of very serious soil degradation, except for surface erosion of the exposed soft laterite at building sites and along improperly located roadways.

The vesicular laterite serves as one of the more important storage sources of groundwater for domestic use as shown convincingly by Sirimanne (1952). Expanding urban settlements east of Colombo city around Malabe-Kottawa-Homagama is exerting a severe strain on this limited groundwater supply. Development of factory sites for industrial development is also causing major modification and deformation of the natural surface landscape. This adversely affects the landscape hydrology, especially in the low-lying paddy lands that are being filled up at a rapid pace.

Proper landscape management of new building sites, industrial sites, and roadways should be considered a high priority requirement for this soilscape.

Further inland, most parts of this soilscape are under rubber plantations and homestead settlements. The erosivity of the rainfall is the highest in rubber-growing districts of the country. Because of the high structural stability of these rubber-growing soils, and minimum infiltration rate of soils exceeding the highest rainfall intensities experienced in this region, soil erosion is usually absent under a good rubber plantation canopy. Soil loss studies undertaken by the Rubber Research Institute indicate the importance of ground covers at the replanting stage of old rubber with improved clones. Soil loss in a rubber plantation that was clean weeded was 24 MT/ha, while with a cover crop the soil loss was 0.5 MT/ha. The present system of rubber plantation could be considered a very sustainable soil and land management system.

3. *Nitisol Landscape*

The typical Kandyan mixed forest garden settlement is found on this landscape. As mentioned in earlier chapters, because of the excellent physical properties of the reddish brown latosolic soils (Rhodic Nitisols) as well as their resistance to erosion, they are among the most productive soils of the mid-country.

As commented by Krishnarajah (1984), *"a homestead with mixed plantings of various tree species to meet home needs had been practised for generations in the mid-country. This land use system had provided the needs of the settlers and ensured the use of the land as a renewable resource, and passed it down to the next generation."* Runoff and soil loss under this system were measured and it was observed that the maximum runoff recorded was only 8 percent of the rainfall, while the soil loss recorded was only 0.05 MT/ha per year.

It is also reported from further studies that only 10 percent of the sediment load in the streams is derived from agricultural land and that the balance 90 percent is derived mainly from housing sites and road cuts. This again emphasizes the need for proper landscape management in locating building sites and in tracing new roads on this nitisol landscape. It also refutes the common allegation that erosion and land degradation derive mainly from agricultural land. The opening up of large scale housing sites on hill slopes and cutting of roads on this type of terrain is a serious threat of environmental degradation.

It is also known that most of the so-called degraded tea lands occur in the mid-country. In order to minimize and prevent further degradation of such lands they should be reforested or transformed to the Kandyan forest garden type of settlement. It should also be noted that recovery of vegetation on these nitisols is very rapid, and hence the relevance of forest garden type of land use.

4. *Soilscape Unit No. 14 - RYP with Mottled Subsoil*

This soilscape is mainly confined to the southwestern part of the Kurunegala district and occurs on undulating terrain. Coconut plantations, both estate and small holder, is the predominant land use on the upland, and rain-fed or semi-irrigated paddy predominates the lowland.

According to currently adopted and recommended cultivation practices for coconut (Mahindapala 1991) and the last thirty years of research conducted on the nutrient status of soils by the Coconut Research Institute, coconut cultivation can be considered a very sustainable land management system. Because of the good natural grass cover, erosion hazards are minimized, except during the high intensity storms that prevail at the end of the February-March dry season. A high proportion of the biomass is recycled within a coconut plantation and this promotes sustainability.

Incentives that are being provided for intercropping on coconut lands, and the promotion of nitrogen-fixing trees in between coconut palms will enhance biomass production, which will help to further enhance the sustainability of coconut plantations.

5. *Latosol-Regosol Landscape*

Because of the flat landscape and high infiltration rates of these soils, there is no erosion hazard experienced on these soils. For the red and yellow latosols, cashew as a rain-fed tree crop is considered the best replacement to the present natural forest. As demonstrated at Kondachchi, it could be considered a sustainable form of land use that requires very little external inputs, except for pest control. However, because of the fragile chemical fertility of the latosols, clean felling of the natural forest is not recommended. Strip clearing and progressive removal of the original forest are considered more sustainable.

The present land use on most of the cultivable sandy regosols is coconut, which again in its present form is highly sustainable. Caution should, however, be exercised on the intensive agriculture being promoted in the Kalpitiya peninsula, which involves a rapid and frequent recycling of the shallow groundwater and the ensuing chemical pollution.

6. *Reddish Brown Earth Landscape*

Although this soilscape is recognized as the most extensive and important one in the country, it poses some of the more difficult and intractable problems in respect of its sustainable management. These problems have been identified and described in several important publications over the last 40 years. An earlier landmark publication is that of Abyeratne (1962), and a later one that of Panabokke (1977), both of which have diagnosed and defined the main parameters of the problems. An updated review and analysis of the core of the problems and the advances made to date in tackling some of the more serious ones is contained in the proceedings of a workshop held under the auspices of Section B of SLAAS, edited by Mapa (1993).

Intensive research has been conducted on very similar soils, rhodustalfs and paleustalfs, in the west African environment at the International Institute of Tropical Agriculture (IITA) over the last 25 years. The conclusions of the IITA research are similar and equally valid and applicable to the reddish brown earths of Sri Lanka. In both situations, it is observed that under low population pressure shifting cultivation, involving mixed crops, intercropping can maintain a vegetative cover over the soil for a long period and thereby maintain a threshold level of soil organic matter. This equilibrium, however, breaks down under high population pressure and a shortening of the chena cycle. This is the crux of the problem as explicitly stated by Abeyratne (1962).

The organic matter level in the soil is important in maintaining an active population of soil organisms to promote organic matter mineralization and pesticide decomposition, minimize development of pest organisms, and promote and stabilize a favourable physical condition of the soil. The level of organic matter may be taken as an indicator of the sustainability of a soil management system. If the organic matter level falls below a certain threshold level for the soil of this land use system, then this whole system is likely to be nonsustainable.

The major thrust of soil management research at the Maha Iluppallama research station over the recent decade has been, quite logically, to evolve soil and land management methods that could combine soil erosion control and organic matter maintenance in the soil. It should be borne in mind that while a sustainable land use system should preserve the productive status of the soil, it must also do so within the limits set by economic and social constraints.

Methods of alley cropping and conservation farming that have been developed over the recent decade by Handawela (1986) and Weerakoon (1992) are quite logical and readily adaptable to this soilscape. However, in common with the IITA alley cropping systems, these have yet to find much farmer acceptance because of economic reasons. Since most of the European and western agricultural production systems have their sustainability supported by state subsidies in various forms, it is a moot question whether conservation farming in the dry zone environment should receive some degree of subsidy in order to sustain its productivity and protect the soil from degradation. Clearly, there is a need to transfer resources from some other sectors of the economy for promoting renewable resource management and adoption of sustainable practices.

As mentioned in the previous chapter, one should treat with caution the general belief that large reserves of high quality land are available within this soilscape. Up to around 30 percent of the surface area of this soilscape is made up of shallow, gravelly, and lithic phases of reddish brown earths interspersed with rock knob plains and eroded lands. All lands within such categories should be left under their natural vegetation cover or else allocated for nature reserves in order to ensure their sustainability.

7. *Noncalcic Brown Soil Landscape*

This discussion is confined to that part of the soilscape that occurs in the Ampara-Batticaloa district within the AER of DL2, and excludes that which falls within the Kurunegala district in the AER of IL3.

Three main factors contribute to the overall fragility of this soilscape. The rough irregular slopes and terrain, the very poorly structured and coarse-textured soils, and the slow regeneration of the forest cover.

Sustainable management of the upland soils is very difficult under any circumstances. The vast extent of illuk grass *(imperata)* is itself a clear index of the fragility of these soils. Small pockets of forest are found interspersed with the grassland. The most sustainable land use for the uplands would be forestry, or else agro forestry on the more gentle terrains, which have moderately deep soils.

Wetland rice cultivation in the bottomlands is a very sustainable form of land use, especially if combined with measures to enhance the present low levels of organic matter content of the paddy soils.

8. *Reddish Brown Earth - Immature Brown Loam Landscape*

In relative ranking, this could be considered the most fragile of the different soilscapes of the country. The steep, hilly, and rolling nature of the terrain, the poor structural stability of the soils and the erosive nature of the rainfall, especially in that portion of the soilscape located within the AER of IM1, all contribute towards the relative fragility of this soil landscape.

Although the road infrastructure is not highly developed within this soilscape area, inroads are now being made even to less accessible parts by footpaths and rudimentary tracks. From the environment standpoint this soilscape is located within the strategic transitional area between the lower and middle peneplains, which need to be conserved and properly managed. Much of the catchment area of the Randenigala and Rantambe reservoirs is also located within this soilscape and hence the importance of proper conservation.

The steep and hilly terrain should be left under natural vegetation or some form of forestry, while the rolling terrain could be used with advantage for homestead settlements or seasonal cropping on properly bench-terraced land as seen around Madugoda.

Wherever dry weather flow from small streams could be diverted, terraced paddy lands have been developed, which make use of this dry season flow for productive vegetable horticulture. The highly windswept portions of this landscape that lie athwart the immediate rain shadow of the southwest monsoon are best left undisturbed in their present state. Regeneration of vegetation in these windswept areas is very difficult and the natural vegetation should not be removed or altered.

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GLOSSARY of Selected Technical Terms

A horizon - The upper horizon of a mineral soil normally having the maximum organic matter content and maximum biological activity.

Acid rocks - Rocks containing 10% or more free quartz.

Acrisols - Acid, low base status soils with Bt horizons (FAO Soil Legend).

Albic horizon - a pale, relatively coarse, eluvial horizon.

Alfisols - Mineral soils that have an argillic or natric horizon which is at least 35% base saturated.

Alluvial soil - A soil developing from recently deposited alluvium.

Alluvium - Mixed, unconsolidated sediments deposited by water flowing in rivers and streams.

Argic B horizon - A subsurface horizon which has a distinctly higher clay content than the overlying horizon.

Argillic horizon - A diagnostic illuvial B horizon characterized by an accumulation of silicate clays (USDA Soil Taxonomy and FAO Legend).

Barrier beach - Elongate sand ridge rising slightly above high-tide level.

B horizon - A soil horizon usually beneath the A which is characterized by one or both of the following - (a) an accumulation of silicate clays. (b) a blocky structure.

Base saturation percentage - The proporation of the adsorption complex of a soil saturated with exchangeable cations other than hydrogen and aluminum.

Basement - Igneous or metamorphic rocks, often Pre-Cambrian, that unconformably underlie unmetamorphosed sedimentary strata.

Basic rocks - Quartz-free (usually igneous) rocks.

Bedrock - The solid rock underlying soils.

Block uplift - Vertical uplift of extensive blocks of the crust.

Bog soils - Marsh soils, including mucks and peats.

Braided - Of a river tract, having more than one drainage channel.

C horizon - An unconsolidated layer (not strictly a horizon) beneath the solum that is relatively little afected by biological activity and pedogenesis.

Cambic horizon - A horizon which has been altered or changed by soil-forming processes and lacking dark colours and organic matter (USDA Soil Taxonomy and FAO Legend).

Cambisols - Soils wih a cambic B horizon as a feature (FAO Soil Legend).

Catena - A sequence of soils derived from similar parent material, climatic conditions, but having different characteristics due to vriation in relief and drainage.

Cation - exchange capacity (CEC) - The maximum amount of exchangeable cations that a soil can absorb.

Chromic - Of soils with high chroma, strong brown to red B horizons (FAO soil legend).

Classification, soil - The systematic arrangement of soils into groups or categories based on their characteristics.

Clay mineral - Clay-sized inorganic material (usually crystalline) found in soils and less than 0.002 mm in diameter.

Colluvium - a deposit of soil material and rock fragments accumulated at the base of steep slopes.

Columnar soil structure - structure similar to prismatic structure but with rounded tops to individual peds.

Concretion - a chemical compound, such as calcium carbonate or iron oxide, in the form of a grain or nodule.

Consistence (or consistency) - The combination of properties of soil material that determine its resistance to crushing and its ability to be moulded or changed in shape. Described in terms such as loose, friable, firm, soft etc.

Cutans - Term for clay skins in ped and pore surfaces, which may be evidence of illuviation.

Diagnostic horizon - Soil horizon, some or all of whose properties are used for classification purposes.

Dissected - Of a plateau, into which a number of valleys have ben carved by erosion subsequent to uplift.

Dune - Accumulation of loose sand, a mound of blown sand.

Dystric - With low base sturation, less than 50% in the upper subsoil (FAO Soil Legend).

Eluviation - The removal of soil material from a layer of soil.

Eutric - With high base saturation, 50% or more in the upper subsoil (FAO Soil Legend).

Erosion pavement - A layer of coarse rounded fragments remaining on the surface after removal of fine particles by erosion.

Family - See soil family.

Ferralsols - Strongly weathered tropical soils with an oxic B horizon (FAO Soil Legend).

Ferromagnesian minerals - Silicate minerals rich in iron and magnesium, usually dark coloured.

Ferruginous - Denoting rocks or minerals containing iron, oftern resulting in a reddish colour.

Flood plain - The land bordering a river or stream, built up of sediments from overflow and usually still subject to inundation.

Fluvial - Of or pertaining to rivers.

Gley - Conditions of poor drainage resulting in reduction of iron and other elements and in grey colours and nottles.

Geomorphology - The science of land forms.

Gleysols - Soils in which gleying is predoninnt (FAO Soil Legend).

Great group - A category in the USDA Soil Taxonomy between that of the suborder and the subgroup.

Great Soil Group - Any one of the broad groups of soils with fundemental characteristics in common.

Groundwater - Water that fills all the unblocked pores of underlying material below the water-table, which is the upper limit of saturation.

Half-bog soils - Soils with dark-brown or black peaty, material over greyish and rust-mottled mineral soil.

Haplic - Modal, normal typical.

Histosols - Soils characterized by their high organic matter content such as bog soils and half-bog soils.

Horizon - A layer of soil, approximately parallel to the soil surface, with distinct characteristics produced by soil forming processes.

Hydromorphic soils - A suborder of intrazonal soils, all formed under conditions of poor drainage in marshes, swamps, seepage areas, or flats.

Hydrology - The science that relates to the water of the earth.

Illuviation - the process that is creating or has created an illuvial horizon.

Inceptisols - Soils with one or more diagnostic horizons that are though to form rather quickly and that do not represent significant illuviation.

Inselberg - A steep, rounded outcrop, hill or mountain, usually of granite or gneiss, which stands out above a pediment.

Incised - Cut deep into either a floodplain or a plateau.

Ironstone - In soil and regolith, hardened plinthite; of laterite.

Land capability - Ranking or rating or land based on the severity of land limitations.

Land classification - The classification of land units into classes and /or subclasses based on its suitability for general or specific purpose uses.

Land element - The simplest landscape unit, with uniform lithology, form, soil and vegetation.

Land evaluation - Interpretation of soils and topography for land use planning purposes.

Land form - The shape of the land, expressed geomorphologically.

Land suitability - Ranking or rating of land for a specific use by closely taking management into account.

Land system - An area or a group of areas throughout which there is a recurring pattern of topography, soils and vegetation.

Leaching - Removal of materials in solution or suspension.

Levee - A raised bank along the side of a river channel in its flood plain.

Luvisols - High base status soils with Bt horizons (FAO Legend).

Luvic - Of soils showing clay illuviation which is not, however, considered to be the dominant soil forming process (FAO Legend).

Monadnock - An isolated residual rock or mountain standing above a peneplain.

Montmorillonite - An alumino -silicate clay mineral with a 2:1 expanding crystal lattice.

Morphology - See soil morphology.

Mottling - Patches of different colour or shades of colour interspersed with the dominant matrix colour.

Natric horizon - An argillic horizon which has columnar structure and is more than 15% saturated with exchangeable sodium.

Nitosols - tropical soils with Bt horizon and prominent, shiny clay skins (FAO Soil Legnd). Now changed to **Nitisols.**

Nodule - See concretion.

Order - The highest category in the USDA Soil Taxonomy, divided into suborders.

Orthic - Common, ordinary, typical.

Outcrop - Strictly, the area over which a rock occurs at, or very close to the surface.

Outlier - An outcrop of a newer rock surrounded by older rocks.

Oxic horizon - Highly weathered diagnostic subsurface horizon from which most of the combined silica has been removed leaving a mixture dominated by hydrous oxide clays.

Oxisols - Soils of the tropical regions characterized by the presence of an oxic horizon.

Parent material - The weathered mineral or organic matter from which the solum of soils is developed by pedogenic processes.

Patana - Rolling grassland in the hilly regions of Sri Lanka.

Ped - A soil agregate such as a crumb, prism, block etc., formed by natural processes.

Pedology - The science of soils.

Pediment - An erosional plain of bedrock, developed between mountain and basin areas.

Pedogenesis - The process of soil formation.

Peneplain - A nearly flat surface of country produced by long periods of subaerial erosion; 'almost a plain'.

Phase - See soil phase

Planosols - Soils with eluviated surface horizons underlain by B horizons more strongly illuviated, cemented or compacted than associated normal soil.

Plateau - An elevated area of generally flat land bounded by abrupt slopes.

Pleistocene - The earlier of the two epochs comprising the Quaternary period from about 1 million years ago.

Plinthite - A highly weathered mixture of sesquioxides of iron and aluminium with quartz and other diluents which occur as red mottles.

Quaternary - The youngest half of the Cainozoic Era made up of Pleistocene and Recent.

Raised beach - An old beach occuring above the present beach, due to rise of the land or to fall in sea levels.

Recent - The last 10,000 years after the Pleistocene.

Red - yellow podzolic soils - Soils formed under warm temperate to tropical, humid climates, under deciduous or coniferous forest vegetation and usually under conditions of good drainage. A zonal greas oil group (USDA 1949 classification system).

Regosols - Any soils without definite genetic horizons and developing from or on deep, unconsolidated, soft mineral deposits (USDA 1949 classification system and FAO Legend).

Rejuvenation - Results of geological uplift or sea-level lowering on a land area; evidence includes incision of river meanders, dissection of plateaux.

Rendzinas - Soils with brown or black friable surface horizons underlain by light-grey to pale-yellow calcareous material; developed from soft, highly calcareous parent material.

Residual - Of soil, formed in place or with only slightly downslope displacement in surface horizons.

Rhodic - Of ferralsols with a red to dusky red B horizon (FAO Soil Legend).

River Terrace - A near-horizontal terrace on a valley side, representing part of an older alluvial valley floor before erosion.

Slickensides - Polished, grooved ped surfaces in swelling and cracking clays, often lying diagonally, commonest in the subsoil of vertisols.

Smectite - Montmorillonitic and related clay minerals.

Soil Association - A group of defined soil units (usually soil series) occuring together in a characteristic pattern.

Soil Classification - The systematic arrangement of soils into gruops or categories on the basis of their characteristics.

Soil Complex - A mapping unit of two or more kinds of soil, each of which occurs in areas too small or too intricately mixed with other soils to be mapped separately at a given survey scale.

Soil family - In soil calssification one of the categories intermediate between the great soil group and the soil series.

Soil genesis - The mode of origin of a soil with specia reference to processes responsible for the development of the solum from the unconsolidated material.

Soil Horizon - A layer of soil, usually approximately parallel to the soil surface, with distinct characteristics produced by soil-forming processes.

Soil Morphology - The constitution of a soil including the texture, structure, consistence, colour and other physical, chemical and biological properties.

Soilscape - The pedologic portion of the landscape; contraction of soil landscape.

Soil Series - The basic unit of soil and consisting of soils which are essentially alike in all major characteristics except the texture of the A horizon.

Solonetz Soils - Soils with surface horizons of varying degrees of friability underlain by dark hard soil, ordinarily with columnar structure. This hard layer is usually highly alkaline.

Subgroup - See great group.

Tectonic - Structural, belonging to the structure of the earth's crust.

Terrace - A horizontal or gently inclined bench-like step.

Tertiary - The earlier part of the Cenozoic period.

Transgression - Gradual expansion of a shallow sea resulting in progressive submergence of the land as and when the sea level rises.

Toposequence - A repeating sequence of soils, slopes or vegetation correlated to relief. See also catena and soils association.

Udic - Moist soil moisture regime.

Ultisols - Soils of humid areas characterized by the presence of either an argillic horizon or a fragipan each of which is <35% saturated with bases.

Ustic - Dry soil moisture regime.

Vertisols - Soils high in swelling clays which crack widely upon drying.

Villu - Graslands of back water swamps of major rivers.

Xanthic - Of ferralsols with a yellow to pale yellow B horizon (FAO Soil Legend).

APPENDIX (I)

The formative elements of the names of the major soil groupings and soil units are given below, explaining the etymology of the name. (L = Latin, Gr = Greek)

Formative elements used for naming Major Soil Groupings (level 1)

ACRISOLS : from L. acer, acetum, strong acid; connotative of low base saturation.

ALISOLS : from L. alumen; connotative of high aluminium content.

ANTHROSOLS : from Gr. anthropos, man; connotative of human activities.

ARENOSOLS : from L. arena, sand; connotative of weakly developed coarse textured soils.

CAMBISOLS : from L. cambiare, to change; connotative of changes in colour, structure and consistence.

FERRALSOLS : from L. ferrum and alumen; connotative of a high content of sesquioxides.

FLUVISOLS : from L. fluvius, river; connotative of alluvial deposits.

GLEYSOLS : from Russian local name gley, mucky soil mass; connotative of an excess of water.

HISTOSOLS : from Gr. histos, tissue; connotative of fresh or partly decomposed organic material.

LEPTOSOLS : from Gr. leptos, thin; connotative of weakly developed shallow soils.

LIXISOLS : from L. lixivia, washing; connotative of accumulation of clay and strong weathering.

LUVISOLS : from L. luere, to wash, "lessiver", connotative of accumulation of clay.

NITISOLS : from L. nitidus, shiny; connotative of shiny ped faces.

PLANOSOLS : from L. planus, flat, level; connotative of soils generally developed in level or depressed relief with seasonal surface waterlogging.

PLINTHOSOLS : from Gr. plinthos, brick; connotative of mottled clayey materials which harden upon exposure.

PODZOLS : from Russian pod, under and zola, ash; connotative of soils with a strongly bleached horizon.

REGOSOLS : from Gr. rhegos, blanket; connotative of a mantle of loose material overlying the hard core of the earth.

SOLONCHAKS : from Russian sol, salt, and chak; connotative of salty area.

SOLONETZ : from Russian sol, salt, and etz, strongly expressed.

VERTISOLS : from L. vertere, to turn; connotative of turnover of surface soil.

Formative elements used for naming Soil Units (level 2)

ALBIC : from L. albus, white; connotative of strong bleaching.

CALCIC : from L. calx, lime; connotative of accumulation of calcium carbonate.

CAMBIC : from L. cambiare, change; connotative of change in colour, structure or consistence.

CHROMIC : from Gr. chromos, colour, connotative of soils with bright colours.

DYSTRIC : from Gr. dys, ill, dystrophic, infertile; connotative of low base saturation.

EUTRIC : from Gr. eu, good, eutrophic, fertile; connotative of high base saturation.

FERRALIC : from L. ferrum and alumen, connotative of a high content of sesquiodixes.

FERRIC : from L. ferrum, iron ; connotative of ferruginous mottling or an accumulation of iron.

FIBRIC : from L. fibra, fibre; connotative of weakly decomposed organic material.

GLEYIC : from Russian local name gley, mucky soil mass.

HAPLIC :	from Gr. haplos, simple; connotative of solis with a simple, normal horizon sequence.
HUMIC :	from L. humus, earth; rich in organic matter.
LITHIC :	from Gr. lithos, rock; connotative of very thin soils.
LUVIC :	from L. luere, to wash, "lessiver"; connotative of accumulation of clay.
PLINTHIC :	from Gr. plinthos, brick; connotative of mottled clay materials which harden irreversibly upon exposure.
RHODIC :	from Gr. rhodon, rose; connotative of red coloured soils.
SODIC :	from L. sodium; connotative of high content of exchangeable sodium.
TERRIC :	from L. terra, earth; connotative of well decomposed and humified organic materials.
UMBRIC :	from L. umbra, shade; denoting the presence of an umbric A horizon.
VERTIC :	from L. vertere, to turn; connotative of a turnover of surface soil.
XANTHIC :	from Gr. xanthos, yellow; connotative of yellow coloured soils.

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