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RASHTRIYA SAM VIKAS YOJANA, Palakkad

AGRO-ECOLOGICAL UNITS, PALAKKAD DISTRICT

National Bureau of Soil Survey and Land Use Planning (ICAR)

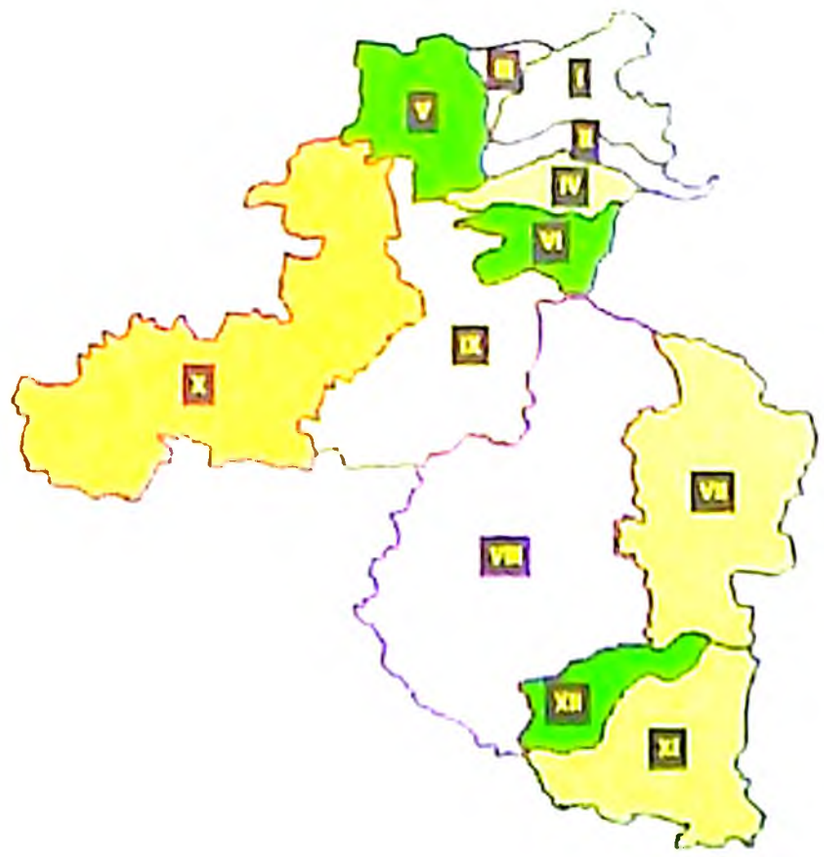
Soil Survey Organization, Kerala

Kerala Agricultural University

RASHTRIYA SAM VIKAS YOJANA, PALAKKAD

AGRO-ECOLOGICAL UNITS, PALAKKAD DISTRICT

Project: Detailed Land Resource Inventory for Precision Agriculture in Part of Palakkad District with Special Reference to Rice Cultivation and Nutrient Management Plan



National Bureau of Soil Survey and Land Use Planning, Regional Centre, Bangalore

In Collaboration with

Soil Survey Organisation, Directorate of Agriculture, Thiruvananthapuram, Kerala

and

Kerala Agricultural University, Thrissur, Kerala

ABOUT NBSS & LUP

The National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Nagpur, a premier institute of Indian Council of Agricultural Research (ICAR), was set up in the year 1976 with the objective of preparing soil-resource maps at village, watershed, taluk, district, state and national levels and to provide research inputs in soil-resource mapping, soil correlation and classification, soil genesis, remote-sensing applications, land evaluation, land-use planning, land-resource management and data-base management using GIS for optimising land use on different kinds of soils in the country. The Bureau has been engaged in carrying out agro-ecological and soil-degradation mapping at the country, state and district levels for qualitative assessment and monitoring of soil health towards viable land-use planning.

The research activities of the Bureau have resulted in identifying soil potentials and problems and the various applications of soil surveys with the ultimate objective of sustainable agricultural development. The Bureau has the mandate to correlate and classify soils of the country and maintain a National Register of all the established soil series. The Institute is also imparting in-service training to staff of soil survey agencies in the area of soil survey, land evaluation, land-use planning and GIS. The Bureau in collaboration with Punjabrao Krishi Vidyapeeth, Akola, and Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, is running post-graduate teaching and research programmes in land-resource management, under which M.Sc. and Ph.D. degrees are awarded. The Regional Centres of the Bureau are associating with SAU's in teaching, research and other academic activities.

The publication "Agro-ecological Units, Palakkad District" was prepared from climate, soil and land information generated during the operation of the project "Detailed Land Resource Inventory for Precision Agriculture in Part of Palakkad District" and provide the required information for agro-ecological unit based crop production technologies and to evolve viable and sustainable land use plans for the district.

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TO OBTAIN COPIES OF THIS REPORT
Please write to:

Director,
National Bureau of Soil Survey and Land Use Planning (NBSS & LUP),
Amravati Road, Nagpur 440 010, India.
Phone : (0712) 2500386, 2500545, 250064
Telefax : +91 – 0712-2500534
Telex : 0712 – 7262 NBSL IN
Telegram : SOILANDBRU
E-mail : director@nbsslup.ernet.in

or

Head,
Regional Centre, NBSS&LUP, UAS Campus, Hebbal, Bangalore 560024
Phone : (080) 23412242, 23510350, 23415683
Telefax : (080) 23510350
Telegram : SOILCORE
E-mail : nbsslup@vsnl.net

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PREFACE

Agro-ecological delineations are made to group lands similar in climate, soils and length of growing period and differentiate from others using the same criteria. The National Bureau of Soil Survey and Land Use Planning under ICAR attempted, for the first time, to prepare a Agro-ecological region map of the country in the late 80s. The Advisory Committee constituted by the ICAR reviewed the map and recommended the publication of the Agro-ecological Region map with 21 regions with technical descriptive notes. The map was based on 50 years of climatic data over 350 meteorological stations and up-to date soils database available in the country. The Director General, ICAR decided to reconcile the map with the Planning Commission, Govt. of India for its wider application. The map was reconciled by making required modifications and a revised 20 region map was published in 1992.

The Bureau, in the year 1999, improved agro-ecological delineation of the country with the publication of 60 agro-ecological subregion (AESR) map. Higher details of soils and narrower range of length of growing period were used in the delineation of AESR.

After the publication of the two maps at the country level the Bureau has been publishing state and district level agro-ecological maps as per project requirement. The Regional Centre, Bangalore conducted detailed soil survey of part of Palakkad district under Rashtriya Sam Vikas Yojana in collaboration with Kerala State Soil Survey Organisation and Kerala Agricultural University. As a part of the program a map of agro-ecological units was prepared for Palakkad district. The delineation was based mainly on climatic types of Thornthwaite and Mather, 1955. Climatic data of 28 stations in the district were collected and moisture index was calculated to classify the climatic types. The rainfall varies from 700 mm to 3200 m and has dominant influence over the other natural resources and land use systems. The North-eastern hilly region and the Eastern parts of the central plains receive lower rainfall than rest of the district. The description of the units includes salient features of the physiography, soils and land use.

This agro-ecological map was presented to collaborators and the Kerala State Planning Board, suggestions carried out and published for the use of various organizations and institutions.

Authors

Project Team

Project Leader: Dr. K.M. Nair, Senior Scientist

Research Associates

Dr. S. Vadivelu, Principal Scientist
Dr. P. Krishnan, Former Principal Scientist
Dr. L.G.K. Naidu, Principal Scientist
Dr. K.S. Anil Kumar, Senior Scientist
Dr. S. Srinivas, Scientist

Technical Associates

Smt. K. Sujatha, Senior Technical Assistant
Shri. Shivappa Angadi, Senior Technical Assistant
Shri. N. Somasekhar, Technical Assistant
Shri. M. Jayaramaiah, Senior Technical Assistant

Research Fellows

Shri. A. K. Anoop, Senior Research Fellow
Shri. Renukaprasanna, Senior Research Fellow
Smt. Divya Vijayan, Senior Research Fellow
Smt. Reeja Prakashan, Senior Research Fellow
Smt. S.V. Hemalatha, Senior Research Fellow
Sri. K. Sivakumar, Research Fellow

Project Co-ordinators

Dr. A.K. Maji, Acting Director, NBSS & LUP, Nagpur

Dr. S. Vadivelu, Head, Regional Centre, NBSS & LUP, Bangalore

Project Funding

Planning Comission, GOI

Rashtriya Sam Vikas Yojana, Palakkad

Technology Development in Agriculture

Co-ordinator: Dr. P. Rajasekharan

Chief (Agriculture Division)

Kerala State Planning Board

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First and foremost, we would like to thank Dr. V.A.K. Sarma, former Principal Scientist who was associated with the project from its inception to the printing of the reports. His meticulous planning and interpretation and his editorial skills have been of immense value in execution of the project.

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Project Team

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AGRO-ECOLOGAL UNITS, PALAKKAD DISTRICT

1. INTRODUCTION

Agricultural productivity and agro-biodiversity of an area are largely governed by the overhead climate and qualities of land and soil. In the tropics and subtropics, where sunlight and temperature are not limiting, it is often the precipitation and the capacity of the land and soil to retain water that control biological productivity. An agro-ecological unit is characterized by distinct ecological responses to the macro-climate, which are reflected in the vegetation, soils and agricultural land use. The concept of agro-ecological delineations was developed by FAO (1976, 1978) with strong emphasis on comparable agro-climatic parameters to delineate agriculturally potential areas suitable for particular crops or combination of crops so that optimum production potential is achieved. Delineation of agro-ecological units at district level is aimed at generation of information for enabling transfer of appropriate agro-technology to meet production requirements.

Agro-ecological delineation of Palakkad district was carried out as part of the project "Detailed Land Resource Inventory for Precision Agriculture in Part of Palakkad District" sponsored by Kerala State Planning Board under the Rashtriya Sam Vikas Yojana for Palakkad. This bulletin presents the methods followed, the salient features of the agro-ecological units and interpretation of the findings for practical applications in land use planning and crop production.

1.1 Geographical Setting

Palakkad, the largest district in Kerala has a total geographical area of 4390 km^2. It is in the east-central part of the state between north latitudes 10° 19' and 11° 15' and east longitudes 76° 01' and 76° 55' (Fig. 1.1). The district is drained by three major river systems, those of the Bharathapuzha, Bhavani and Chalakkudi rivers. The district exhibits varied physiography, with the Nilgiri ranges in the north, the Sahyadri in the south and, between them the Palakkad gap. This gap provides continuity of the central plains of the district to Tamil Nadu Plains. These variations in physiography lead to large changes in climate over relatively short distances.

Fig 1.1 Index map

2. MATERIALS AND METHODS

2.1 Materials

Long-term daily, weekly and monthly rainfall, temperature and PET or ET data for 28 locations spread over the district were obtained from IMD and other sources. The other sources included seed farms, forest department, irrigation department, agricultural department, agricultural research stations (Appendix I). These data sets were checked for internal consistency, edited and used for analysis. Wherever the data sets were of daily data they were directly converted to standard week format. Monthly data sets were converted to weekly figure by dividing them on the basis of available weekly data from the nearest station and expert knowledge. Details of the available data sets are presented in Appendix I. The land and soil information pertaining to the district was extracted from published reports (Krishnan *et al.*, 1996; AIS&LUS, 1991; Nair *et al.*, 2006).

2.2 Methods

2.2.1 Climatic analysis

Mean weekly rainfall values were worked out for each station by averaging the weekly rainfall for the years for which data sets were available. Pre-monsoon, south-west monsoon and north-east monsoon rainfall were calculated by totaling the rainfall each year for the periods January to May (standard weeks 1 to 21), June to September (standard weeks 22 to 39) and October to December (standard weeks 40 to 52) respectively and calculating the average for the years with available data (Appendix II).

For the climatic classification (Thornthwaite and Mather, 1955) the following formula was used.

$$Im = \frac{P - PE}{PE} * 100$$

where Im is the moisture index, P is annual precipitation and PE is potential evapo-transpirataion.

The climatic types presented in the report followed the classification given below.

	Climatic type	Moisture index
A	Per-humid	100 and above
B4	Humid	80 to 100
B3	Humid	60 to 80
B2	Humid	40 to 60
B1	Humid	20 to 40
C2	Moist sub-humid	0 to 20
C1	Dry sub-humid	-33 to 0
D	Semi-arid	-66.7 to -33.3
E	Arid	-66.7 to -100

Probability of moderate and severe drought in the area of influence of a station was computed from annual rainfall data using the method described by IMD (IMD, 2002). A year was

considered normal when the rainfall deviated from normal by 25 per cent or less, and above normal when the rainfall was higher than normal by more than 25 per cent. A year was considered to have moderate drought if the rainfall was 50-75 per cent of the normal and severe drought when the rainfall was less than 50 per cent of the normal rainfall.

Initial and conditional probability of dry or wet weeks were also calculated out for rainfall limit of 20 mm using the Markov Chain of Probability model (Robertson, 1976). A week was considered dry if it received less than 20 mm rainfall.

The soil water balance was worked out from the soil available water capacity (AWC) of the dominant soils, weekly rainfall and potential evapo-transpiration (PET) (Thornthwaite and Mather, 1955). The calculation also provided Actual Evapo-transpiration (AET).

The moisture adequacy index was calculated using the formula

MAI = AET/PET * 100 where AET is the actual evapo-transpiration.

Length of growing period (LGP) for annual crops (without irrigation) for each station for a year was calculated by assuming that the LGP starts when MAI > 50 per cent and ends when MAI is <25 per cent. The average LGP took into consideration 75 per cent probability over the years.

2.2.2 Spatial delineation of agro-ecological units

Analysis of the rainfall (total amount and distribution) recorded at different stations pointed to the complexities engendered in rainfall patterns by the two hill ranges in the north and the south of the district, and the continuity of the central plains with the Tamil Nadu plains. Therefore, the district was initially delineated into three physiographic regions: northern hills, the central plains and southern hills. Parts of both hill regions experience orographic rainfall. It was also noted from the field that elevated ridges had great influence on the distribution of rainfall. Before delineating the agro-ecological units an extensive traverse of the hill areas was undertaken to plot vegetation differences and topographical features. Spatial delineation of agro-ecological units in both hilly regions was realized by taking into account point information (limited climatic station data) and the vegetation and topographic plots.

For the central plains, spatial data comprising the geographical area and point data sets of climatic data stations were organized in a GIS. Spatial interpolation techniques (TIN-based) available with the GIS were used to delineate the agro-ecological units. The delineations of agro-ecological units in the hill regions drawn on paper base were digitized and geo-referenced in the GIS. To generate the district agro-ecological unit map the spatial data sets of the hills and central plains were merged in the GIS. Where possible, minor adjustments in spatial boundaries of the agro-ecological units were done to make them coincide with the nearest panchayat boundaries. The final agro-ecological unit map was composed digitally with all the map elements.

3. RESULTS

Palakkad district was spatially delineated into three agro-climatic zones and 12 agro-ecological units (Fig 3.1). The agro-ecological zones are the northern hilly region, the central plains and the southern hilly region. The agro-ecological units delineated in each zone are described below.

3.1 Northern Hilly Region

3.1.1 Agro-ecological unit I

Agro-ecological unit I lies in the north-eastern corner of Palakkad district and comprises part of Pudur, Agali and Sholayur panchayat of Attappadi Block (Fig. 3.1).

This unit receives the lowest rainfall in the district. The average annual rainfall is in the range 700 to 1000 mm. The bulk of precipitation is received from the north-east monsoon, with very little contribution from the south-west monsoon (Fig. 3.2, Appendix II).

The mean annual temperature is 24.4 °C. April is the hottest month with mean temperature of 26 °C and December the coldest with mean temperature of 23 °C. The climate of the area can be described as dry subhumid (C1) following Thornthwaite's (1948) climatic classification.

The area has probability of moderate drought for three out of ten years. The growing period starts from the last week of September (standard week 39) and continues till the second week of January (standard week 2) of the next year. The total length of growing period is 105 days. The probability of a week being wet is high from the second week of October to the end of November (standard weeks 41 to 48).

The steeply sloping hilly terrain is mostly covered by mixed tropical dry deciduous trees and thorny bushes in various stages of degradation (Fig. 3.3). Many species have strong adaptations for xerophytic life and thorny species occur in large proportion in very dry areas. The forest is poor and the frequency of commercially important species is low. Agriculture is limited, confined to narrow valleys and to hill slopes near hamlets.

Shallow, stony soils dominate the hill slopes (Fig. 3.3). They have yellowish brown, gravelly clay surface soil and subsoil. The surface soil contains about 40 per cent coarse fragments and the subsoil, 60 per cent. The soils are slightly acid in reaction and have moderate medium granular structure in surface soil and moderate medium subangular blocky structure in subsoil.

The narrow valleys and footslopes of hills have moderately deep, gravelly sandy clay loam soils. The surface and subsoil layers contain around 50 per cent coarse fragments. The soils

AGRO-ECOLOGICAL UNITS

PALAKKAD DISTRICT

0 5 10 20 km

Agro-ecological Units

Northern Hilly Region

I Dry subhumid hilly terrain with shallow, stony, moderately deep loam soils, rainfall 700-1000 mm and LGP 105 days.

II Moist subhumid low hills and valleys with very deep, clay soils; rainfall 1000-1500 mm and LGP 245 days.

III Humid hilly terrain with deep, clay soils; rainfall 1500-2000 mm.

IV Perhumid hilly terrain with very deep, clay soils; rainfall 2000-2500 mm and LGP 287 days.

V Perhumid hilly terrain of silent valley with very deep, clay soils, rainfall 2500-3000 mm and LGP 238 days.

VI Perhumid hilly terrain with very deep, clay soils, rainfall 3000-3500 mm and LGP 238 days.

Central Plains

VII Dry subhumid undulating lands with very deep, clay soils, rainfall 1000-1500 mm and LGP 161 days.

VIII Moist subhumid plains with very deep, clay soils, rainfall 1500-2000 mm and LGP 189 days.

IX Humid undulating terrain with very deep, clay soils, rainfall 2000-2500 mm and LGP 203 days.

X Humid undulating terrain with very deep, clay soils, rainfall 2500-3000 mm and LGP 203 days.

Southern Hilly Region

XI Humid hilly terrain with very deep, clay soils; rainfall 2000-2500mm and LGP 252 days.

XII Perhumid hilly terrain with very deep, clay soils, rainfall 3000-3500 mm and LGP 308 days.

References

- District boundary
- State boundary
- Panchayat boundary
- Block boundary
- National highways
- Railway line
- Stream (narrow)
- Stream (broad)
- Water body
- Name of panchayat
- Name of block

MALAPPURAM

TAMIL NADU

THRISSUR

IDUKKI

Attapadi

Mannarkad

Sreekrishnapuram

Pattambi

Ottappalam

Palakkad

Kuzhalmannam

Chittoor

Alathur

Nelliampathy

Nenmara

Malampuzha

Tribala

Note Locational accuracy of geographical features is limited

Fig 3.1 Agro-ecological units map

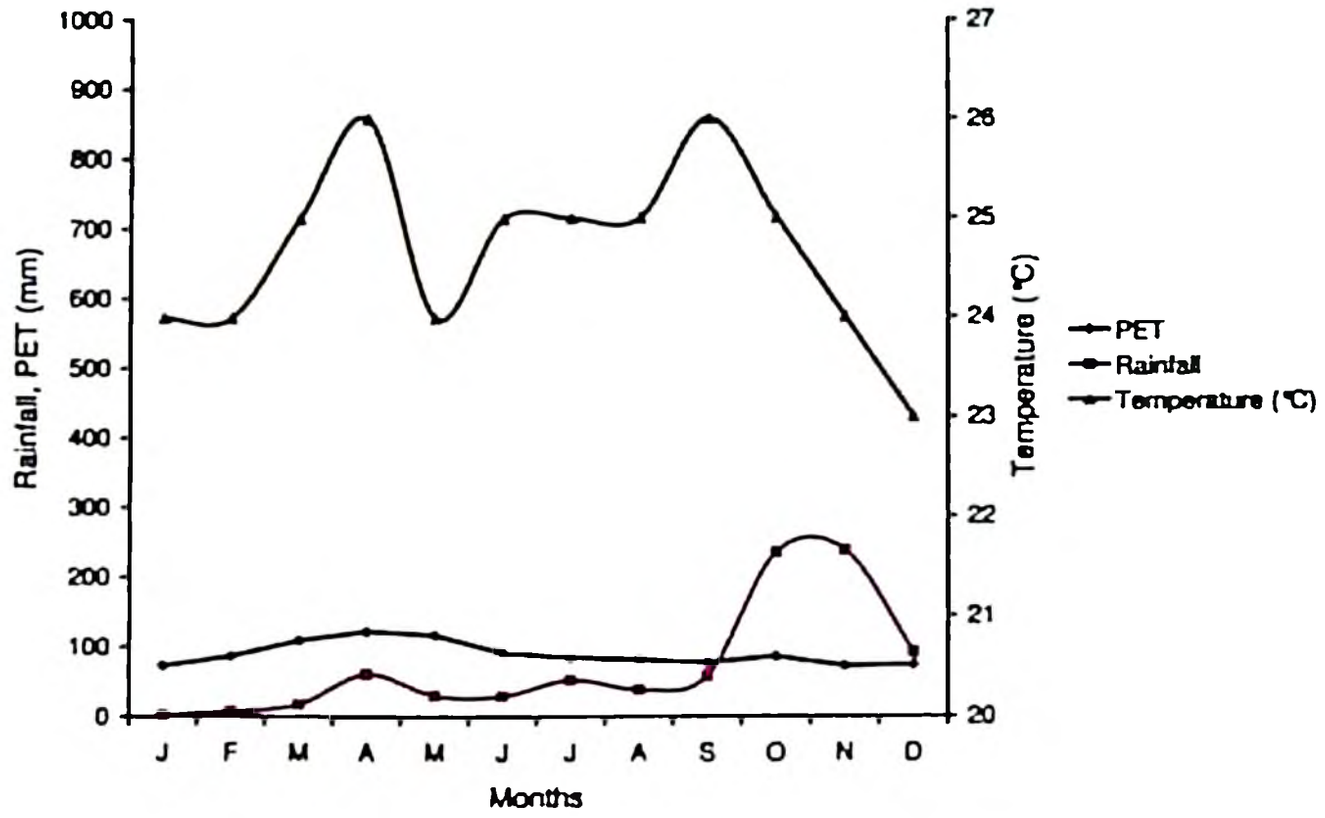

Fig. 3.2 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit I

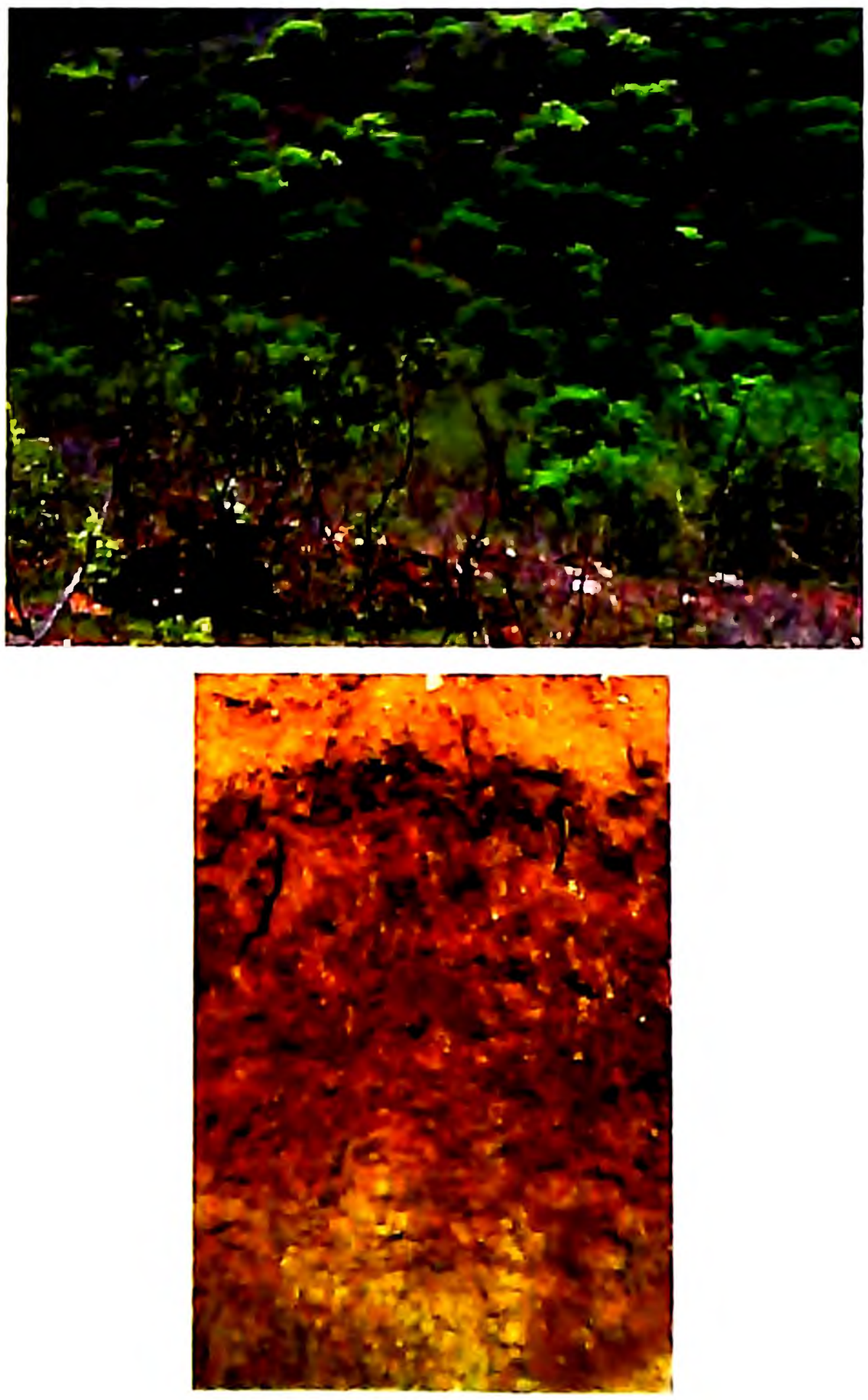

Fig. 3.3 Land and soils of Agro-ecological unit I

are dark reddish brown and have strong subangular blocky structure and neutral or alkaline reaction, and are rich in bases.

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix III.

Very low rainfall, short length of growing period, steeply sloping hilly terrain and shallow, stony soils render the area agriculturally least promising. Only the limited narrow valleys and adjoining footslopes of the hills can be developed through soil and water-conservation measures and used for agriculture. Much of the hill slopes should be preserved under the natural forest vegetation.

3.1.2 Agro-ecological unit II

Agro-ecological unit II is spatially distributed as a narrow strip along the main valley in the central part of Attappady block (Fig. 3.1).

The average annual rainfall of the region is in the range of 1000 to 1500 mm. Precipitation is received from both south-west and north-east monsoons with major share from the latter (Fig. 3.4, Appendix II). The mean annual temperature is 24.2 °C. April and May are the hottest months with mean temperature of 26 °C and December and January the coldest, with mean temperature of 23 °C. The climate of the area can be described as moist subhumid (C2). There is probability of moderate drought in three out of ten years.

The growing period starts from the last week of May (standard week 21) and continues till the fourth week of January of the next year giving a total growing period of 245 days. The probability of a week being wet is high from the third week of June to second week of August (standard weeks 24 to 32) and from the first week of October to the second week of November (standard weeks 40 to 45). The period from the third week of August to the end of September (standard weeks 33 to 39) has high probability of a week being dry.

The low hills of the area are largely barren dotted with patches of degraded forest (Fig. 3.5). Mixed moist deciduous and evergreen forests are found in this unit. They are secondary forests, the climatic climax having been displaced by anthropic disturbance. Evergreen species are often found as undergrowth in these predominantly deciduous forests. The hill slopes are extensively cultivated to annual crops. The valleys are used for a variety of perennial and annual crops with irrigation.

Very deep, dark reddish brown and very dark brown soils are predominant in the area. They are fine textured with strong subangular blocky structure (Appendix IV). The content of coarse fragments range from 15 to 20 per cent and the soils are neutral or slightly alkaline. The base-rich and organic-matter-rich soils can be considered fertile for crop production.

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix IV

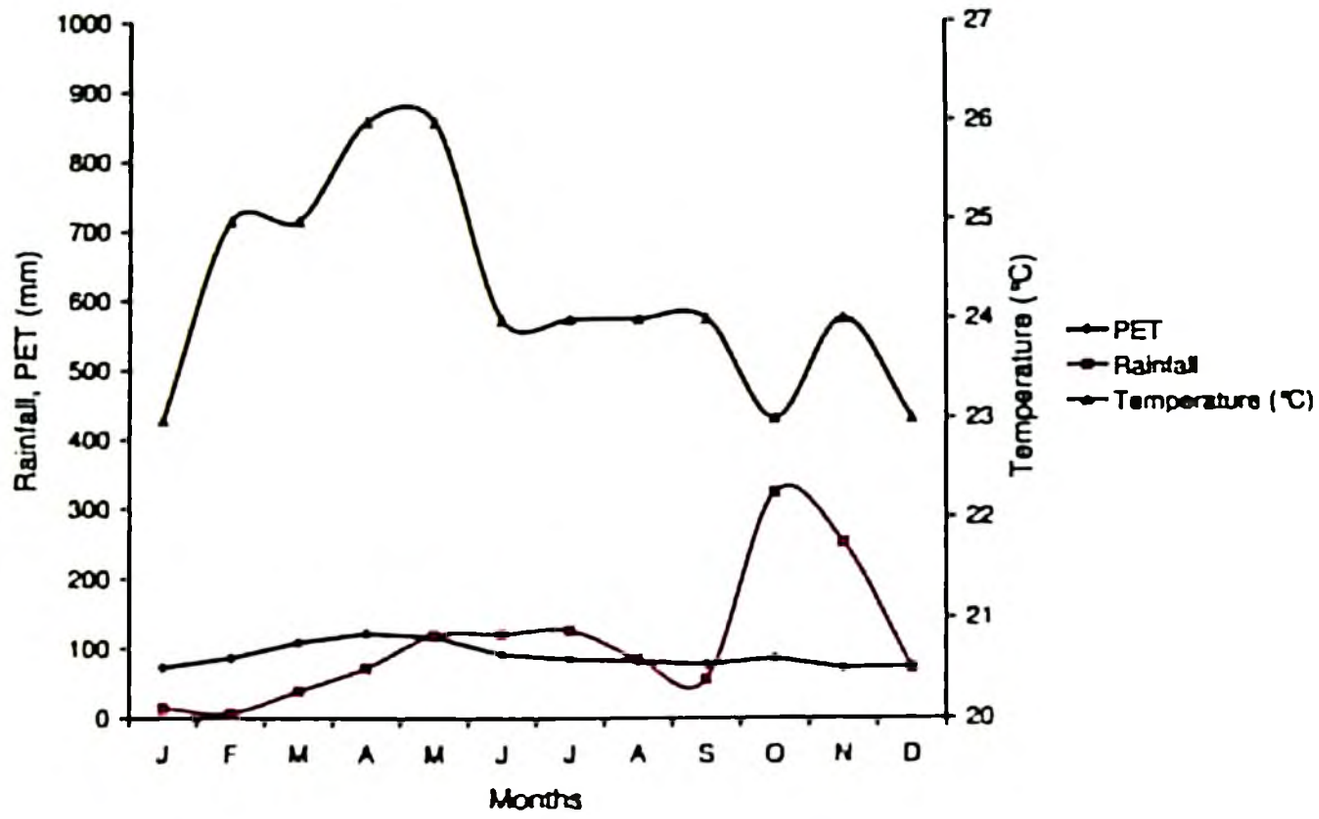

Fig. 3.4 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit II

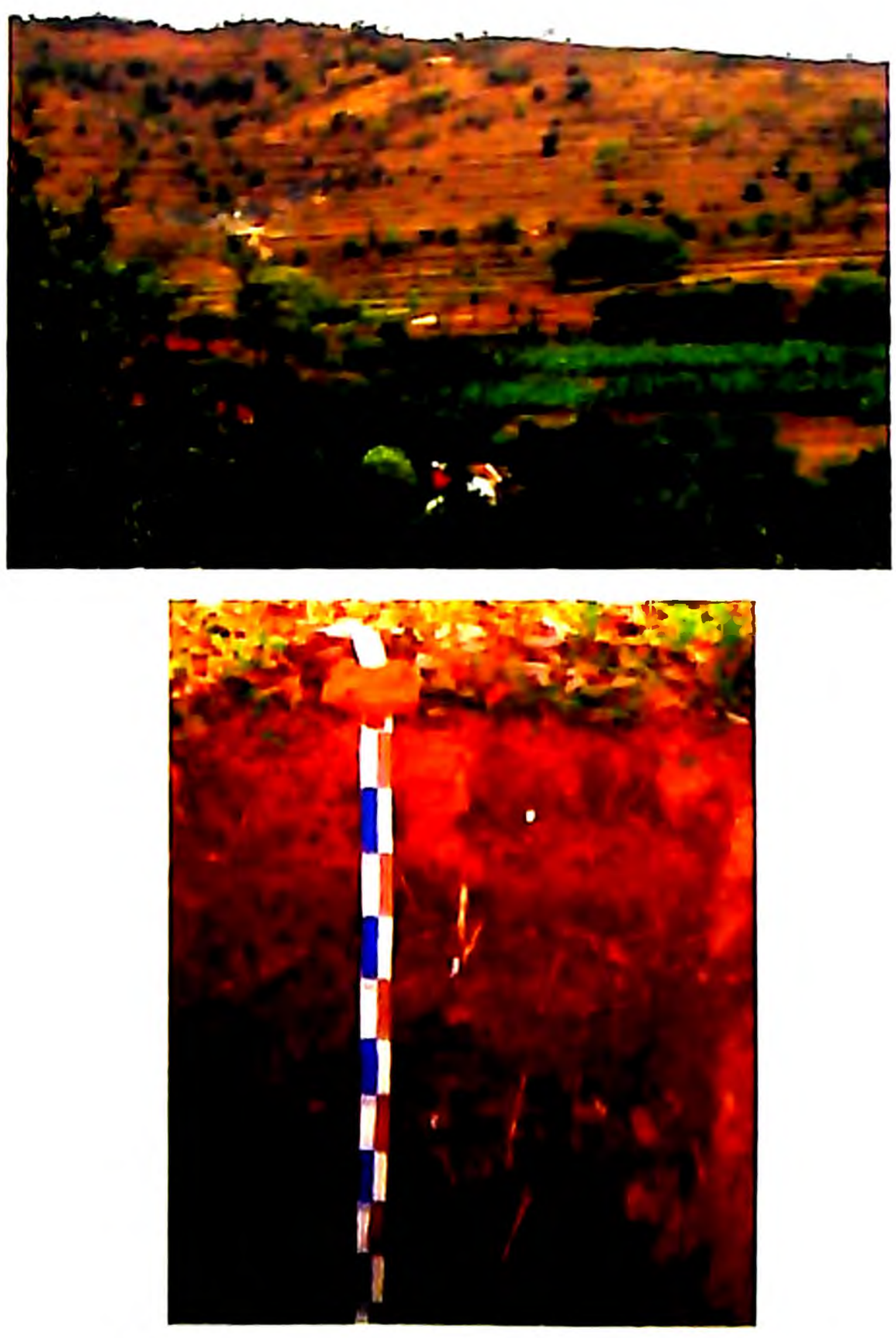

Fig. 3.5 Land and soils of Agro-ecological unit II

With fair share of rainfall received from both monsoons the soils exhibit long crop-growing period. The slope of the land calls for adequate soil-conservation measures for protecting the soils against erosion hazard. A variety of climatically suited plantation, horticultural and annual crops can be grown in the area. The generally lower temperatures in the valley open up the possibility of cultivating high value fruit and vegetable crops.

3.1.3 Agro-ecological unit III

Agro-ecological unit III is a transition from the dry subhumid area in the north-east (unit I) and perhumid area in the north-west (unit V). There was no climatic station to provide data on the climatic parameters. Hence vegetation and topographic features were relied upon for estimating the rainfall and for spatial delineation (Fig. 3.1).

The mean annual rainfall of the area was estimated to be in the range 1500 to 2000 mm. The area can be climatically classified as humid (B4). The steeply sloping hilly terrain is mostly forested with moist deciduous and mixed evergreen forests. The soils are deep and have acid reaction and high organic matter content. Agriculture is very limited, except for a few trees in homesteads.

3.1.4 Agro-ecological unit IV

Agro-ecological unit IV lies south of unit II and consist of hilly terrain (Fig. 3.1). The average annual rainfall ranges from 2000 to 2500 mm and is distinctly bimodal with almost equal precipitation received to from the south-west and the north-east monsoon (Fig. 3.6, Appendix II). The mean annual temperature is 24.7 °C. March to May is the hottest period with mean temperature of 27 °C and July and August are the coldest months with mean temperature of 22.5 °C. The climate of the area can be classified as perhumid (A). The probability of drought is negligible.

The growing period starts from the first week of May (standard week 18) and continues till the second week of February of the following year (standard week 7). The total length of growing period is 287 days. The probability of a week being wet is high from the second week of June to the second week of August (standard weeks 23 to 32) and again for the whole of October (standard weeks 40 to 43). The period from the third week of August to the end of September (standard weeks 33 to 39) has high probability of a week being dry.

The steeply sloping hilly terrain is mostly covered by moist deciduous forests and mixed and moist deciduous evergreen forests. The moist deciduous forests found in the area are dense with luxuriant vegetation. Trees are tall showing characteristic deciduous nature. These forests contain a large number of commercial timber species such as teak. Bamboo is of frequent occurrence. Agricultural activity consists of mixed crops in homesteads (Fig. 3.7) and plantations of tea, coffee and cardamom.

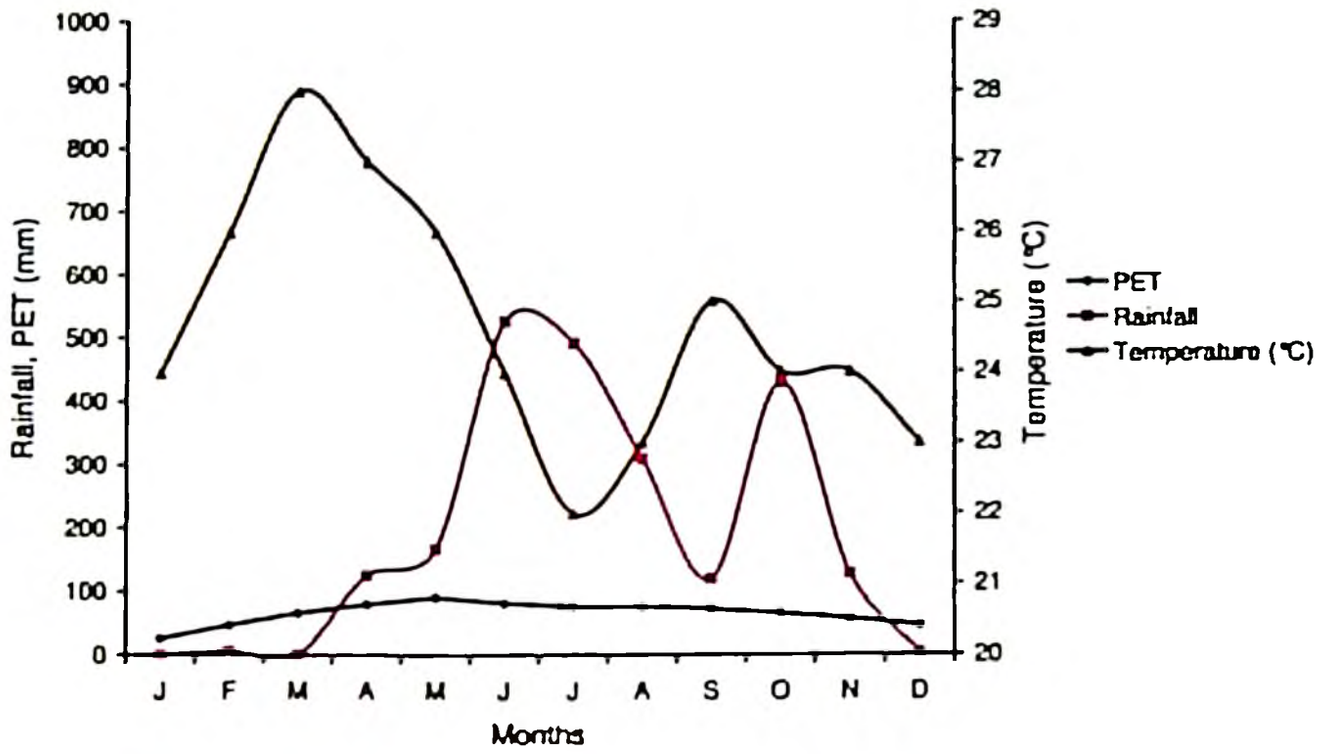

Fig. 3.6 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit IV

Fig. 3.7 Land and soils of Agro-ecological unit IV

The hilly terrain of the unit has deep to very deep, dark brown, fine-textured soils. They are slightly acid or moderately acid and well supplied with bases. The surface soil is rich in organic matter (Fig. 3.7 and Appendix V).

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix V.

Though the climate and soils are favourable for cultivation of a variety of crops, the steep slope of the terrain places severe restrictions on the uses to which the land can be put to. Plantations and tree-based cropping patterns which require minimum soil disturbance and provide complete canopy cover are best suited for the area. Additionally, soil-conservation measures are necessary to prevent soil loss under the intense rainfall during the monsoons.

3.1.5 Agro-ecological unit V

Agro-ecological unit V comprises the Silent Valley forests falling under Palakkad district and lies in the north-west corner of the district (Fig. 3.1). The steeply sloping hilly terrain has almost complete cover of pristine evergreen forest.

The average annual rainfall ranges from 2500 to 3000 mm with almost equal contribution from both monsoons (Fig 3.8, Appendix II). The mean annual temperature is 26 °C. Monthly variation is negligible. The climate is classified as perhumid (A). There is no probability of drought.

The growing period for annual crops start from the third week of May (standard week 20) and continues till the first week of January of the following year. The total length of growing period is 238 days. The probability of a week being wet is high from the second week of June to the third week of August (standard weeks 23 to 34) and from the last week of September to the second week of November (standard weeks 39 to 45). The period from the last week of August to the third week of September (standard weeks 35 to 38) has high probability of a week being dry.

The wet evergreen forests in the area have high species representation and the multiplicity of species is indicative of the state of biological equilibrium (Fig. 3.9). The ground flora of herbs is superposed by three storeys of trees. The trees of the top storey often grow to heights of 50 m or more. Due to closed canopy, the forest floor is devoid of ground cover.

On the fringes of the wet evergreen forests are found closed forest with heterogeneous mixture of evergreen and deciduous species. There are no typical middle stories but undergrowth is often dense. These forests are of secondary origin, the climatic climax having been displaced by direct or indirect human action. Bamboos are some times present in pure patches.

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix VI

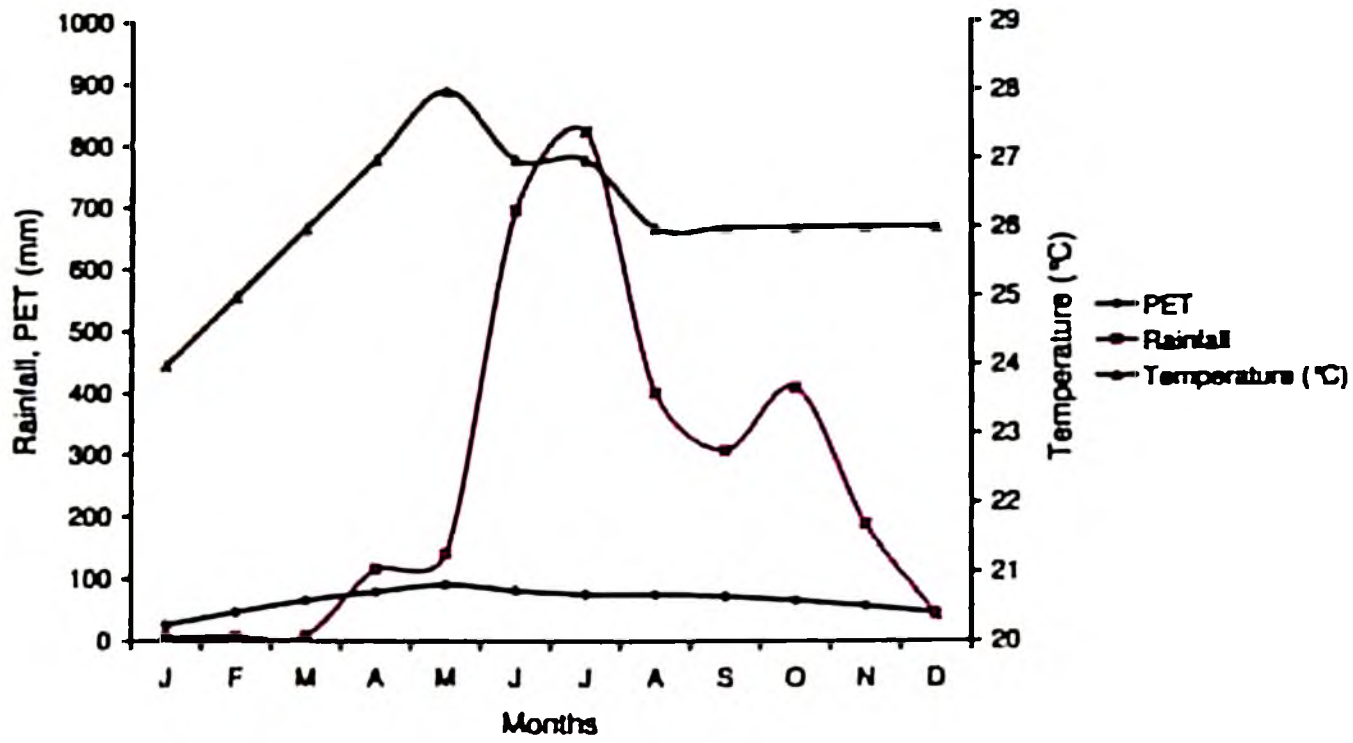

Fig. 3.8 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit V

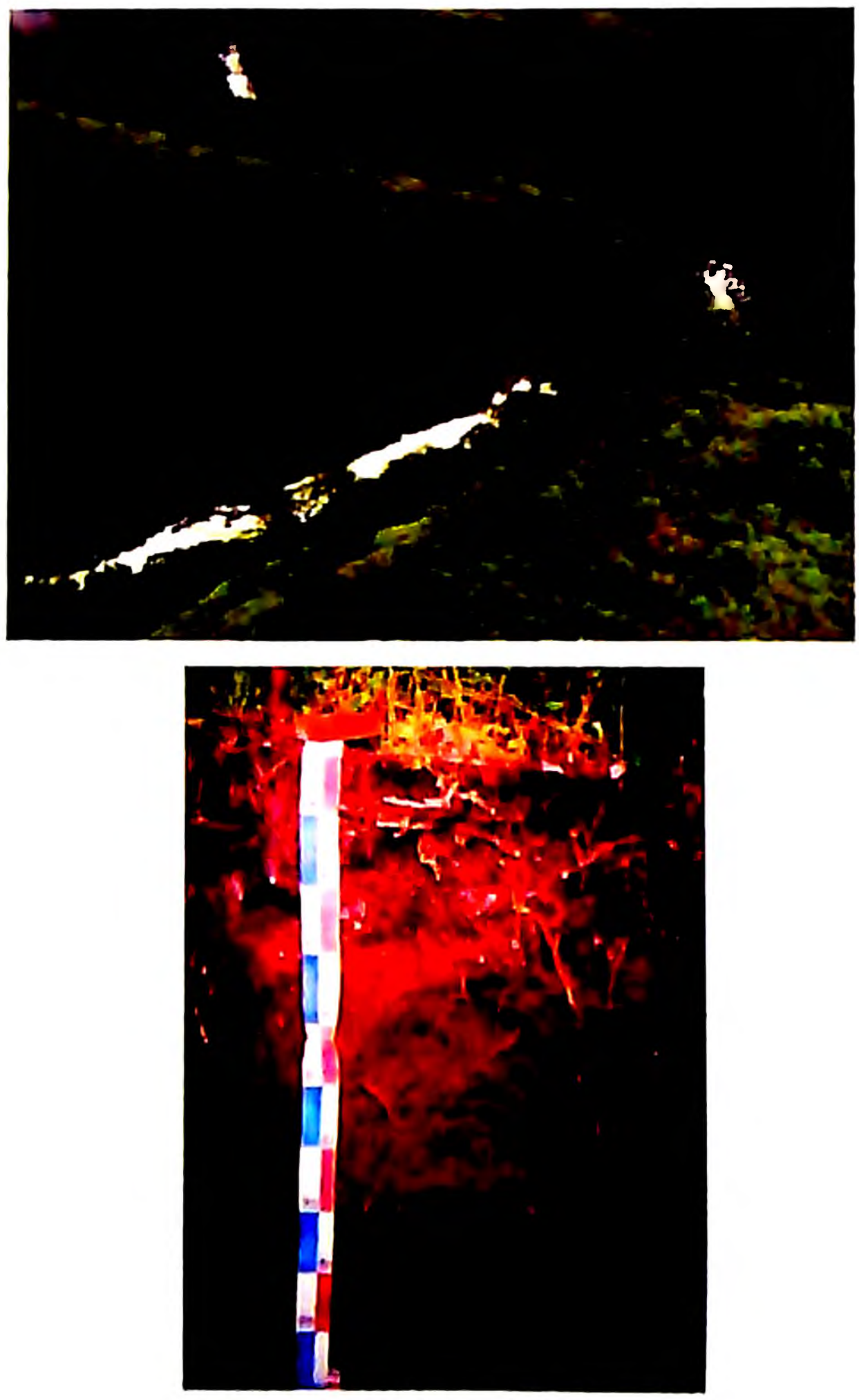

Fig. 3.9 Land and soils of Agro-ecological unit V

The soils developed under extremely humid conditions with dense forest cover are deep and very deep, fine-textured and rich in organic matter. The dark brown to brown soils are strongly acid and poor in bases. The soils are well drained and have subangular blocky structure.

The silent valley area, currently under dense forest vegetation, is an important bio-reserve. From an ecological point of view, the area should be preserved as such.

3.1.6 Agro-ecological unit VI

Agro-ecological unit VI is another forested hilly area in the Northern Hilly region and lies in the southern part of Attappady block (Fig. 3.1).

The average annual rainfall ranges from 3000 to 3500 mm with the major share of rainfall contributed by the southwest monsoon (Fig. 3.10, Appendix II). The high rainfall in the area can be explained by the effect of the mountains rising steeply from the central plains and the consequent orographic rain. The mean annual temperature is 26 °C and the monthly variation is negligible. The climate is classified as perhumid (A).

There is no probability of drought. The growing period for annual crops starts from the third week of May (standard week 20) and continues till the first week of January of the following year (standard week 1). The total length of growing period is 238 days. The probability of a week being wet is high from the first week of June to the third week of November (standard weeks 22 to 47).

The steeply sloping hilly terrain is almost completely covered with evergreen forest except for a few patches of plantations (Fig. 3.11). The wet evergreen forests in the area has high species representation and the multiplicity of species is indicative of the state of biological equilibrium. The ground flora of herbs is superposed by three storeys of trees. The trees of the top storey often grow to 50 m or more. Due to closed canopy, the forest floor is devoid of cover.

On the fringes of the wet evergreen forests are found closed forests with heterogeneous mixture of evergreen and deciduous species. There are no typical middle stories but the undergrowth is often dense. These forests are of secondary origin, the climatic climax having been displaced by direct or indirect human action. Bamboos are often present in pure patches.

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix VII.

The soils of the area are deep and very deep, yellowish brown, fine-textured with subangular blocky structure (Fig. 3.11). They are rich in organic matter, slightly or moderately acid in reaction and fairly well supplied with bases.

The area under dense natural vegetation is better left undisturbed.

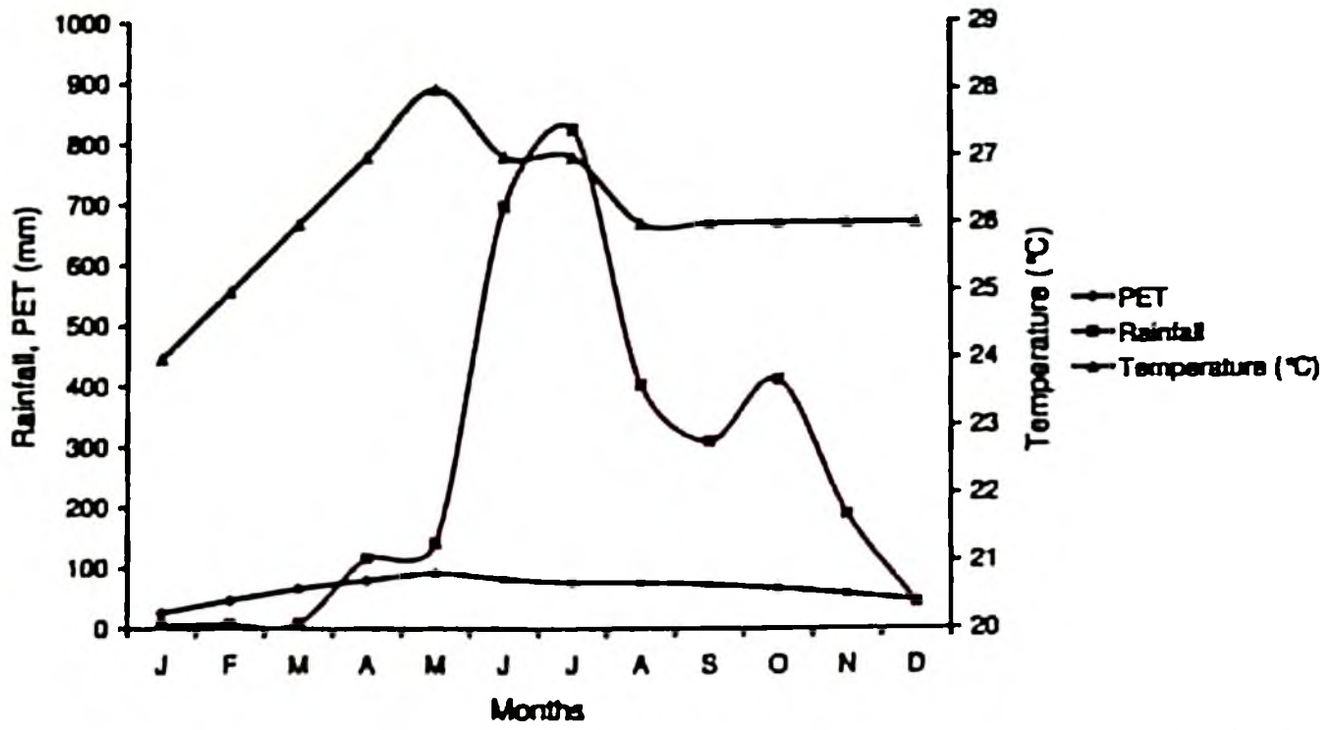

Fig. 3.10 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit VI

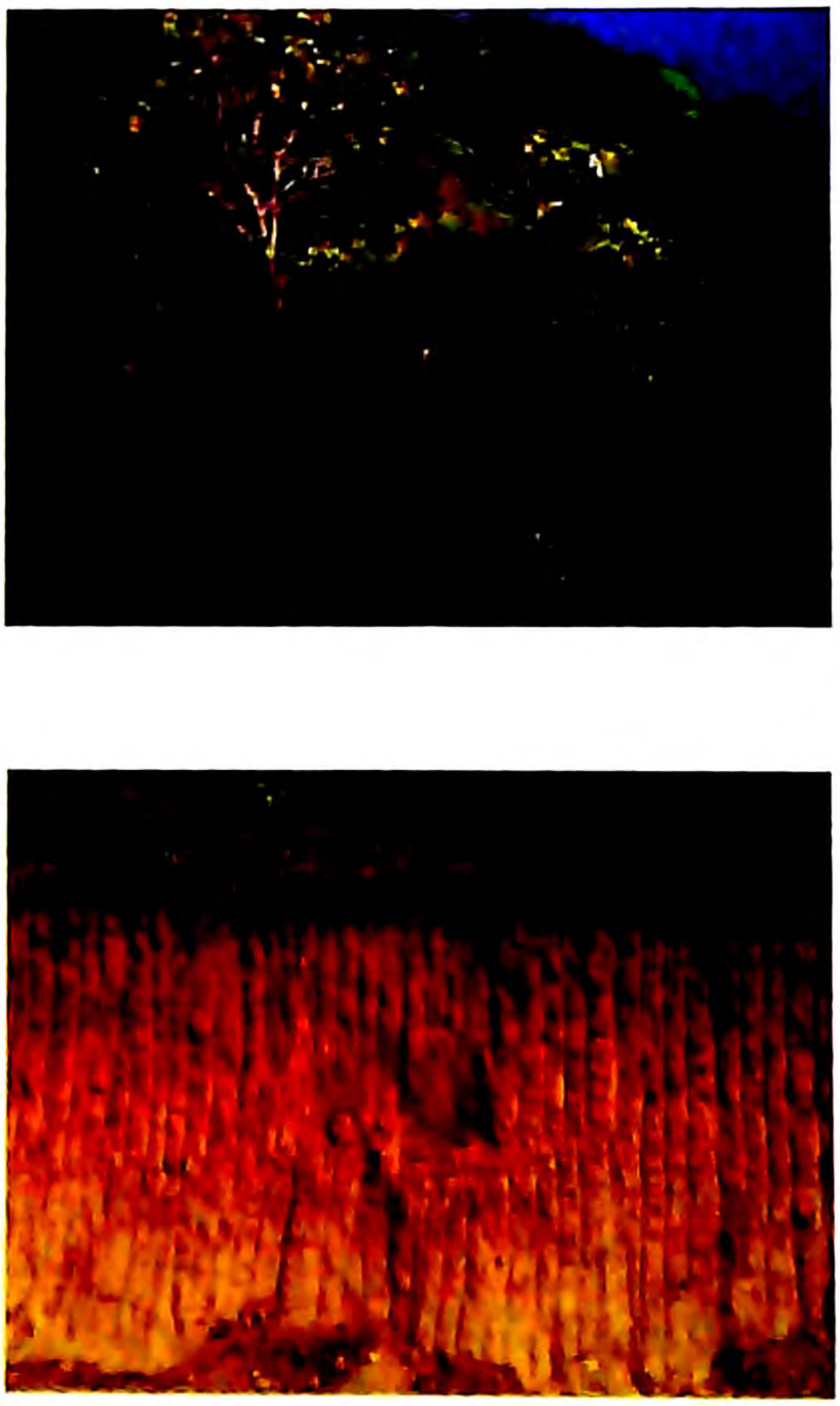

Fig. 3.11 Land and soils of Agro-ecological unit VI

3.2 Central Plains

3.2.1 Agro-ecological unit VII

Agro-ecological unit VII is delineated in the eastern part of the district bordering Tamil Nadu and comprises the whole of Chittur and parts of Kollengode and Malampuzha blocks (Fig. 3.1).

The area receives the lowest rainfall in the plains with annual average in the range of 1000 to 1500 mm. Bulk of the precipitation is received from the south-west monsoon, but a small distinct peak occurs during the north-east monsoon season too (Fig. 3.12, Appendix II). The mean annual temperature is 27.7 °C. March and April are the hottest months with mean temperature of 31 °C and July is the coldest month with mean temperature of 25 °C. The climate can be classified as dry subhumid (C1). The area experiences moderate drought in three out of ten years.

The growing period for annual crops (without irrigation) starts from the fourth week of June (standard week 25) and continues till the last week of November (standard week 48). The total length of growing period is 161 days. However, there is a high probability of soil-moisture deficit during September and October. The probability of a week being wet is high from the third week of August (standard weeks 24 to 34), in the last week of October and in the first week of November (standard weeks 43 and 44). The period from the last week of August (standard week 35) to the third week of October (standard week 42) has high probability of a week being dry.

The undulating terrain with rolling lands and broad valleys is intensively cultivated to a variety of annual and perennial crops (Fig. 3.13). The unirrigated crops are groundnut, jowar, maize and cotton. Rice and vegetables are predominant in the irrigated valleys. Coconut plantations in this unit are often irrigated. Two distinct kinds of soils with their variants occur in the uplands of the unit. The well-drained, higher positions within the uplands have deep, reddish, fine-textured soils. They are neutral, slightly alkaline or slightly acid and are base rich.

The nearly level lower parts of the uplands and the areas adjoining valleys have deep and very deep, grayish (or black), heavy clay soils. These clay soils exhibit swell-shrink behaviour and consequently develop deep cracks during summer. The soils have alkaline reaction, are base-rich and often have free calcium carbonate. They have poor workability and hence cultural operations have to be done at the appropriate moisture content. These soils are locally known as black cotton soils.

The valleys too have deep and very deep, clay soils rich in bases, alkaline in reaction. They too show swell-shrink character, but less pronouncedly than the true black cotton soils.

The area has the highest potential for agricultural development, though it suffers from low and erratic rainfall. The potential emanates from the favourable terrain and soil characteristics. Both upland and low land soils, though poor in organic matter are considered very fertile because of their favourable reaction, high capacity for retaining water and nutrients, and the abundance of bases.

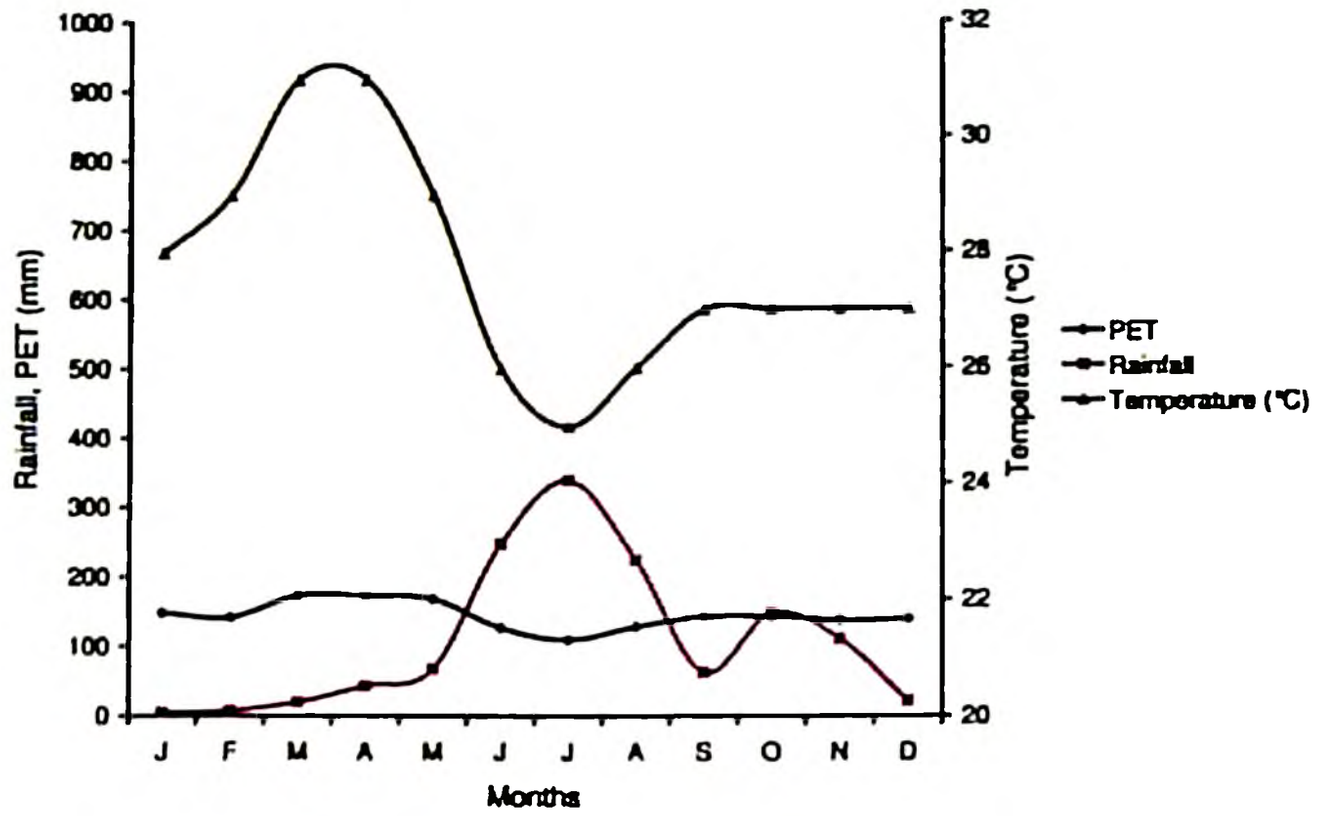

Fig. 3.10 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit VII

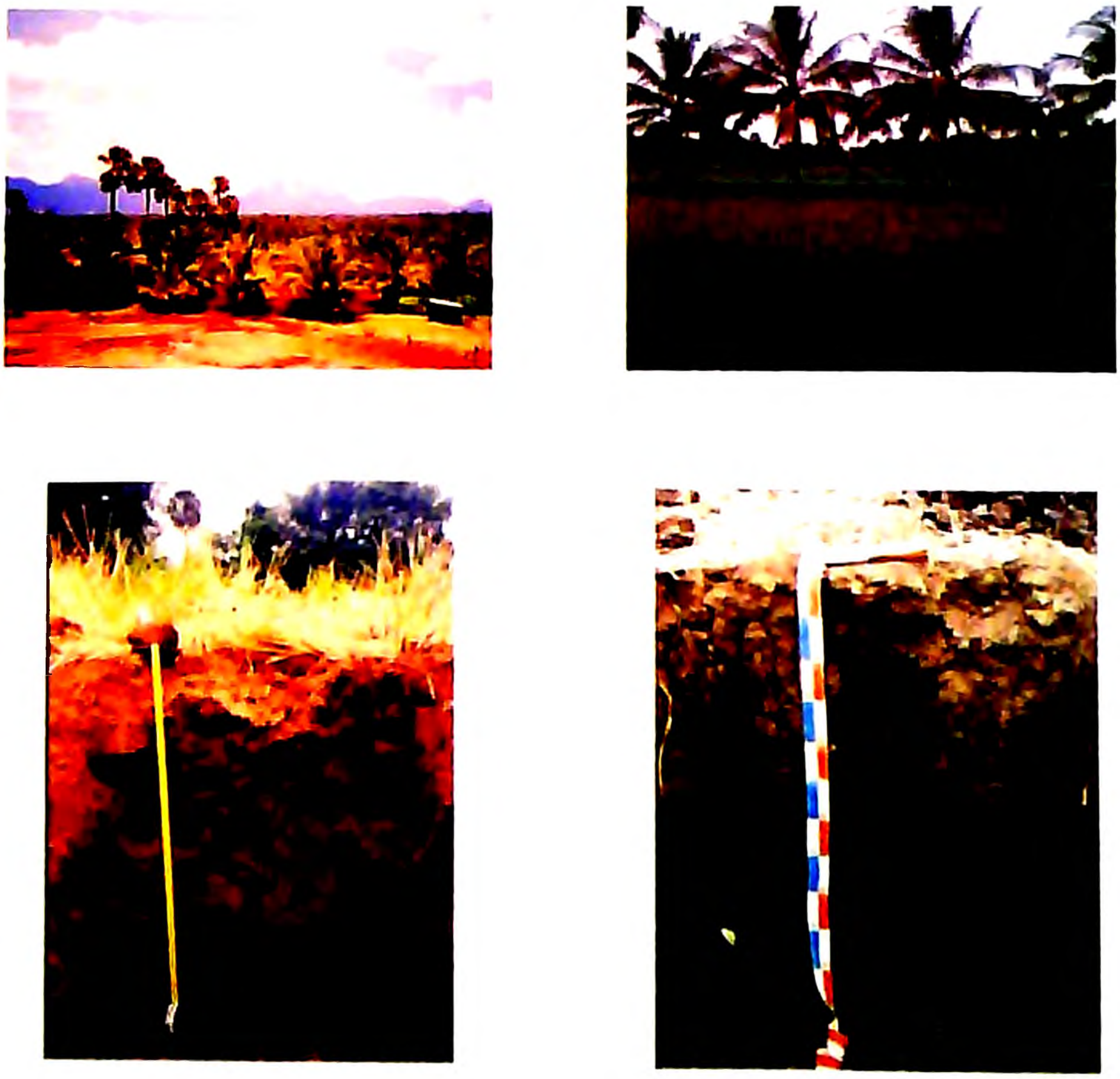

Fig. 3.11 Land and soils of Agro-ecological unit VII

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix VIII.

This drought-prone and low-rainfall unit is only partially serviced by irrigation canals. Complete coverage can ensure very high production, especially of high-value vegetable and fruit crops. Plantation crops like coconut require irrigation as the dry period is substantial and there is probability of drought in three out of ten years. Drip irrigation is the best to reduce the quantity of water required.

3.2.2 Agro-ecological unit VIII

Agro-ecological unit VIII comprises parts of Kollengode and Malampuzha blocks and the whole of Alathur, Nenmara and Kuzhalmannam blocks. It is transitional from the drier eastern parts to the humid western portions of the district (Fig. 3.1).

The average annual rainfall ranges from 1500 to 2000 mm. Bulk of the precipitation is received from the south-west monsoon (Fig. 3.14, Appendix II). The rainfall increases in the east-west direction. The mean annual temperature is 27.7 °C. March and April are the hottest months with mean temperature of 31 °C; July is the coldest month with mean temperature of 25 °C. Climatically the area can be classified as moist subhumid (C2). The probability of moderate drought is two years in a block of ten years.

The growing period for annual crops starts from the second week of June (standard week 23) and continues till the first week of December (standard week 49). Total length of growing period is 189 days. However, there is a high probability of soil- moisture deficit during September. The probability of a week being wet is high from the second week of June to the end of August (standard weeks 23 to 35) and again from the last week of September to the second week of November (standard weeks 39 to 45). The first three weeks of September (standard weeks 36 to 38) have high probability of a week being dry.

The gently sloping plains with occasional undulating terrain and broad valleys are intensively cultivated (Fig. 3.15). The uplands are mostly under coconut and other plantations whereas the low lands are cultivated to two crops of rice. The first rice crop is often rain-fed while the second is fully irrigated.

The gently sloping and occasionally undulating terrain constituting the uplands has deep and very deep, dark brown or dark reddish brown soils. The soils are often fine- textured and have moderately strong subangular blocky structure. The reaction of the surface soil ranges from slightly acid in the east of the unit to strongly acid in the west. In the subsoil the reaction tends to go to neutral with increasing depth. The exchange capacity and base saturation are low compared to those of soils of the eastern region (agro-ecological unit VII). There is a general decline in soil fertility from east to west.

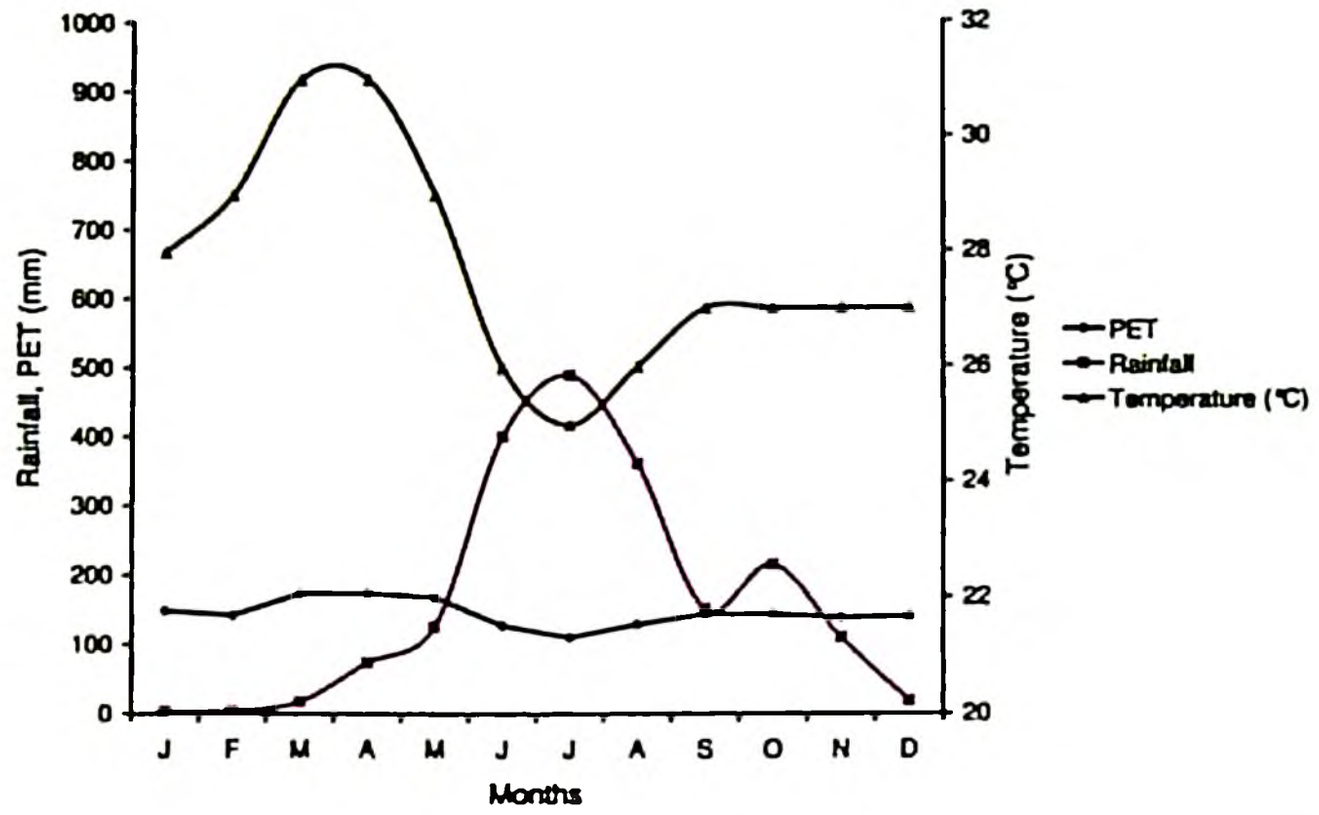

Fig. 3.14 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit VIII

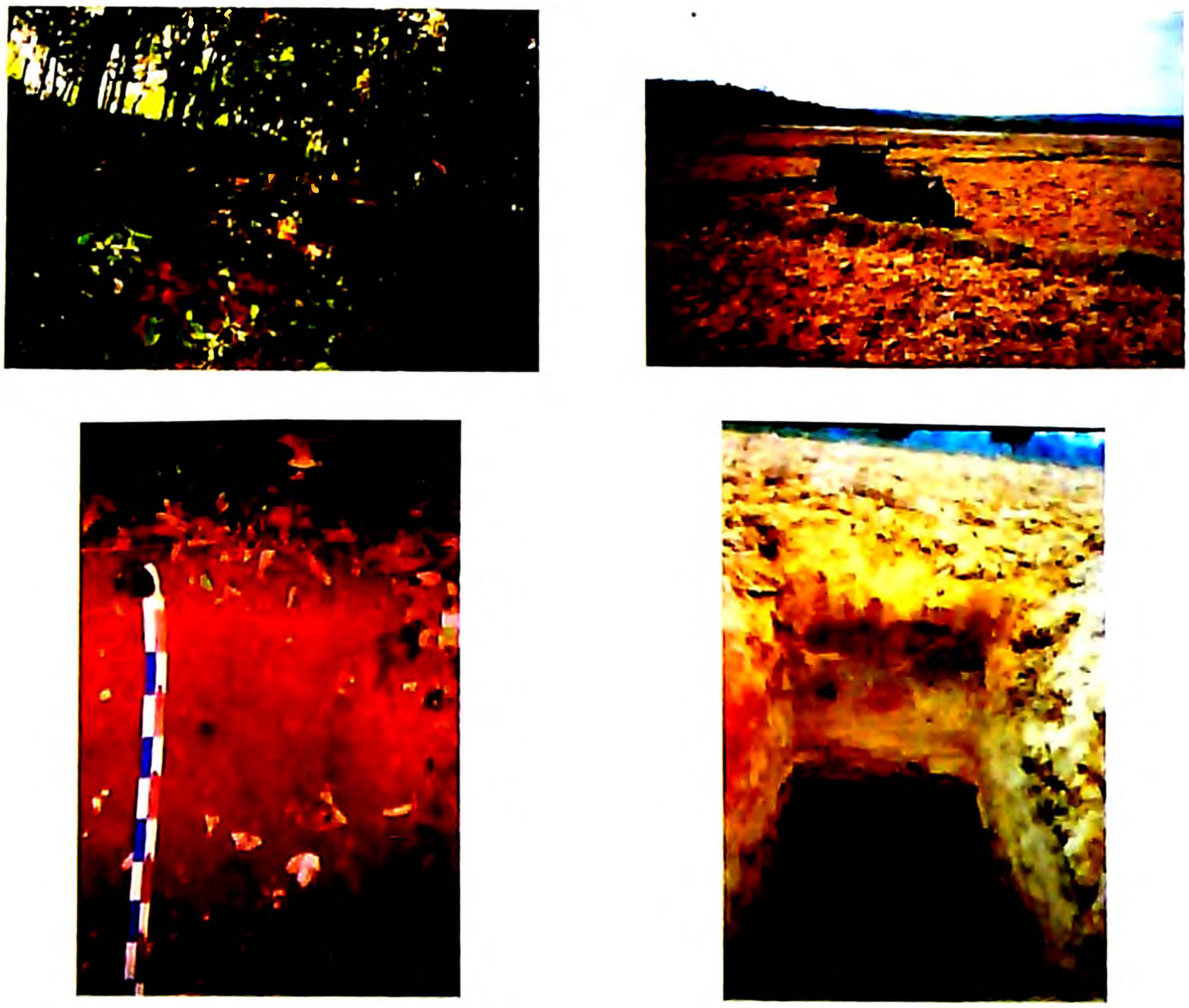

Fig. 3.15 Land and soils of Agro-ecological unit VIII

The low land soils, mostly under rice paddies, also have deep and very deep, brownish soils. These soils are fine-textured and have subangular blocky structure except in the surface layer where puddling associated with rice cultivation has obliterated much of the structural development. They are slightly acid or moderately acid in the surface soil and neutral or slightly alkaline in the subsoil layers. Soil acidity tends to increase towards west. The base saturation is moderate. The low land soils are moderately fertile. However, the organic matter content is low in most soils.

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix IX.

The gently sloping lands with broad valleys, having deep, fine-textured soils have very good agricultural potential. The uplands can be used for a variety of plantation crops taking advantage of the moist subhumid climate. The low lands are ideal for rice production. The unit is well serviced by a network of irrigation canals, besides having good potential for groundwater. Maintenance of soil fertility is essential for enhancing crop production. Provision of micro-irrigation for plantation crops on uplands should substantially increase productivity. Liming of soils to neutralize acidity of surface soils is essential. Rice productivity in this tract can be considerably improved by better agronomic management of the crop and avoidance of continuous flooding of rice paddies.

3.2.3 Agro-ecological unit IX

Agro-ecological unit IX comprises parts of Mannarkkad, Ottappalam and Pattambi blocks (Fig. 3.1).

The average annual rainfall ranges from 2000 to 2500 mm. Bulk of the precipitation is from the south-west monsoon (Fig. 3.16, Appendix II). The mean annual temperature is 27.7 °C. March and April are the hottest months with mean temperature of 31 °C; July is the coldest month with mean temperature of 25 °C. Climatically the area can be classified as humid (B1). The probability of drought is negligible.

The growing period starts from the third week of May (standard week 20) and continues till the end of November (standard week 48). The total length of growing period is 203 days. The probability of a week being wet is high from the second week of June to the last week of August (standard weeks 23 to 35) and from the last week of September to the first week of November (standard weeks 39 to 44). The first three weeks of September (standard week 36 to 38) have high probability of a week being dry.

The undulating uplands with broad valleys are mostly under cultivation (Fig. 3.17). The uplands mostly have plantation crops like coconut and rubber while valleys are cultivated to rice.

The undulating terrain with rolling lands, low hills and valleys has deep, yellowish red, fine-textured soils in the uplands. These lateritized soils have strong subangular blocky structure

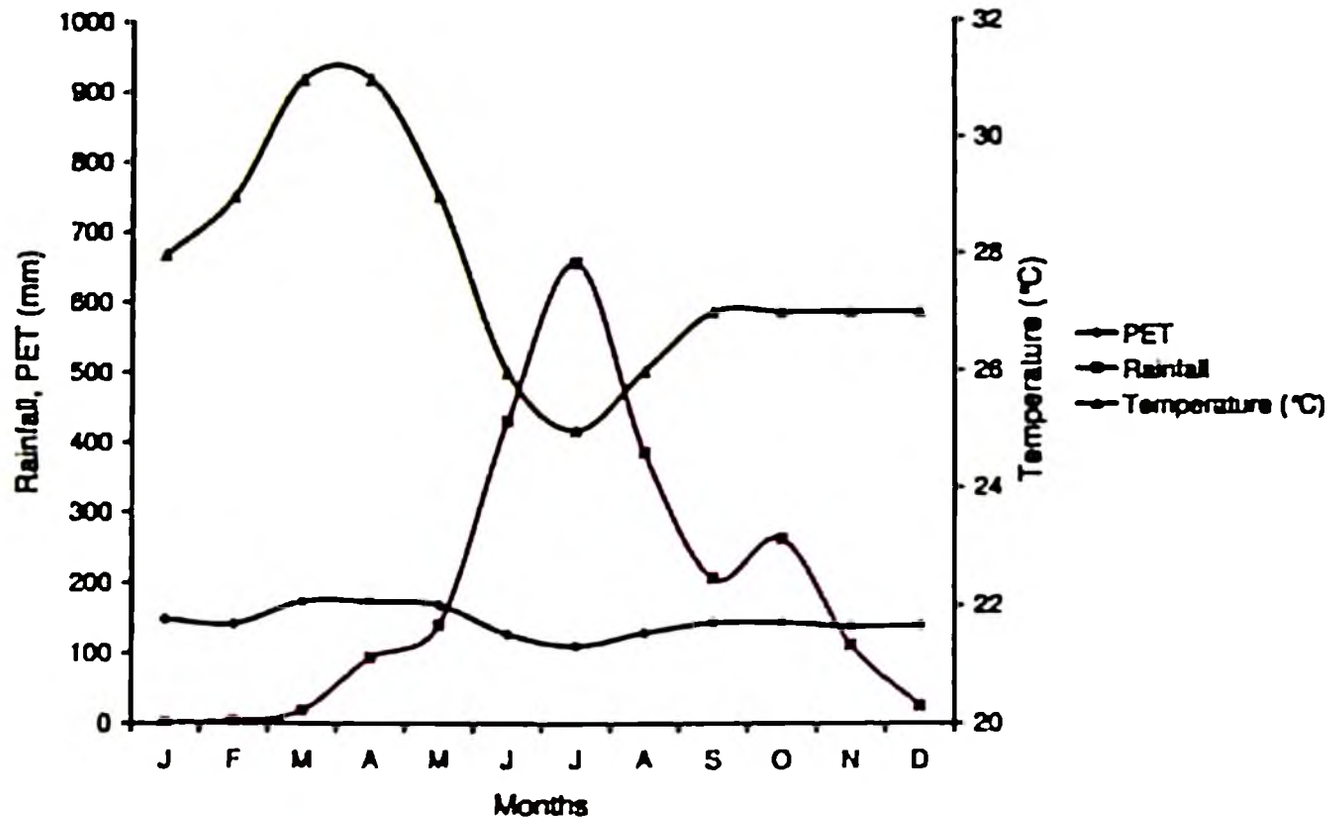

Fig. 3.16 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit IX

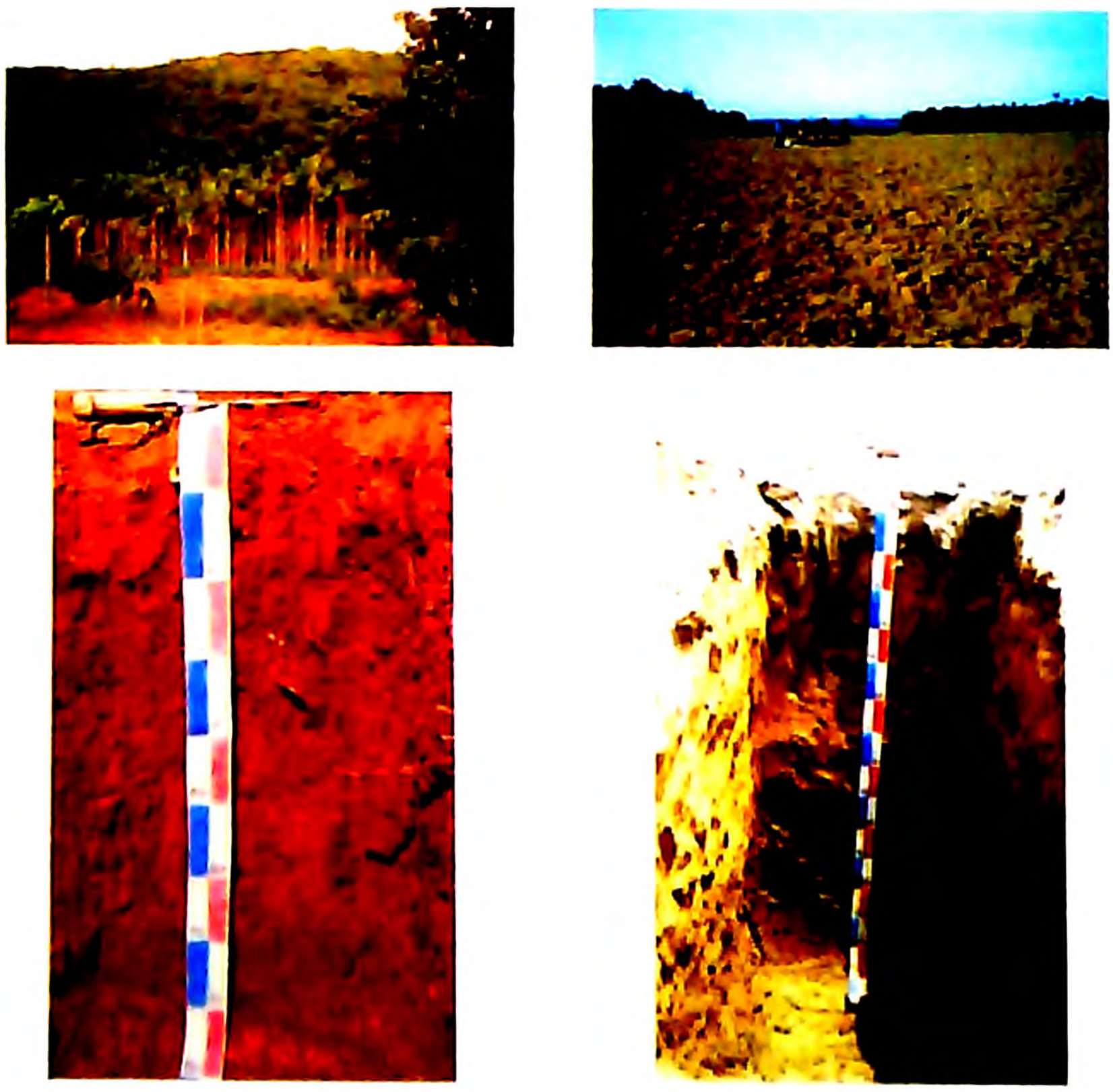

Fig. 3.17 Land and soils of Agro-ecological unit IX

and are often gravelly. The soil reaction is strongly acid and the soils have low cation exchange capacity and base content, properties contributing to the inherent fertility of soils.

The soils of the valleys are very deep, dark brown and fine textured. They too are strongly acid, low in cation exchange capacity and base content.

The humid climate and deep, well-drained soils are favourable for production of a variety of crops. The sloping terrain is best used for plantation crops which require minimum tillage operations. The annual crop production may be confined to nearly level parts of the uplands or in areas protected by soil-conservation measures. Plantation crop production system will be benefited by provision of drip irrigation during the fairly long dry period.

The best land-use system for low lands is rice. An added advantage of rice production in the valleys is the recharge of ground water. Vegetable production in rice paddies is a profitable option during summer months, taking advantage of ground water.

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix X.

The soils being strongly acid and low in nutrient retention, fertility levels need special attention. Regular liming is strongly recommended to neutralize the acidity as well as enhance base saturation. Addition of organic matter and chemical fertilizers can ensure profitable crop production from the soils of the unit.

3.2.4 Agro-ecological unit X

Agro-ecological unit X lies in the western part of the district and comprises parts of Mannarkkad, Ottappalam and Pattambi blocks (Fig. 3.1).

The average annual rainfall ranges from 2500 to 3000 mm and the bulk of it is from the south-west monsoon (Fig. 3.18, Appendix II). The mean annual temperature is 27.7 °C. March and April are the hottest months with mean temperature of 31 °C and July the coldest month with mean temperature of 25 °C. Climatically the area can be classified as humid (B3). The probability of drought is negligible.

The growing period for annual crops starts from the third week of May (standard week 20) and continues till the end of November (standard week 48). The total length of growing period is 203 days. The probability of a week being wet is high from the second week of June to the last week of August (standard weeks 23 to 35) and from the last week of September to the first week of November (standard weeks 39 to 44). The first three weeks of September (standard weeks 36 to 38) have high probability of a week being dry.

The undulating uplands of the unit are cultivated to a variety of plantation crops, predominantly coconut and rubber. The valleys are mostly under rice paddies, plantain and vegetables (Fig. 3.19).

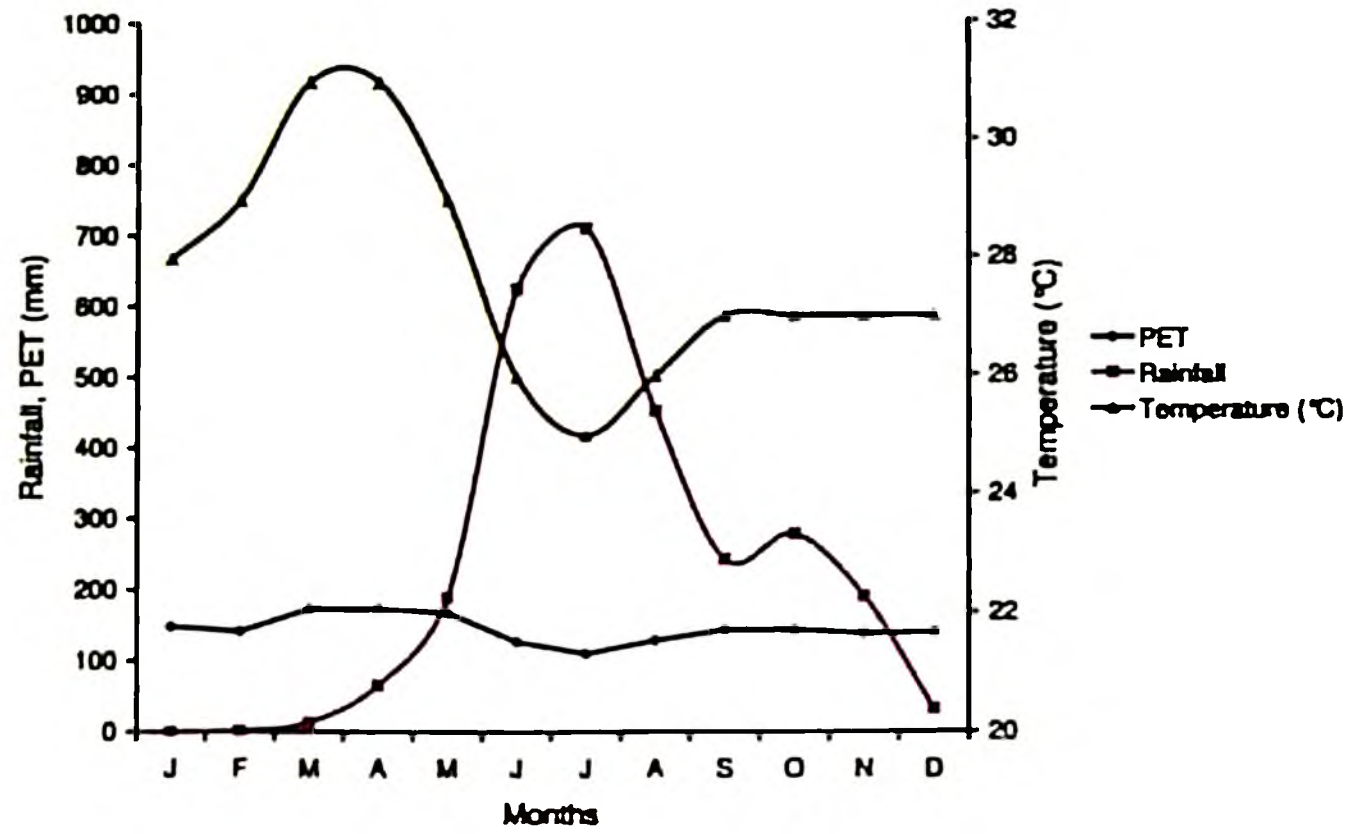

Fig. 3.18 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit X

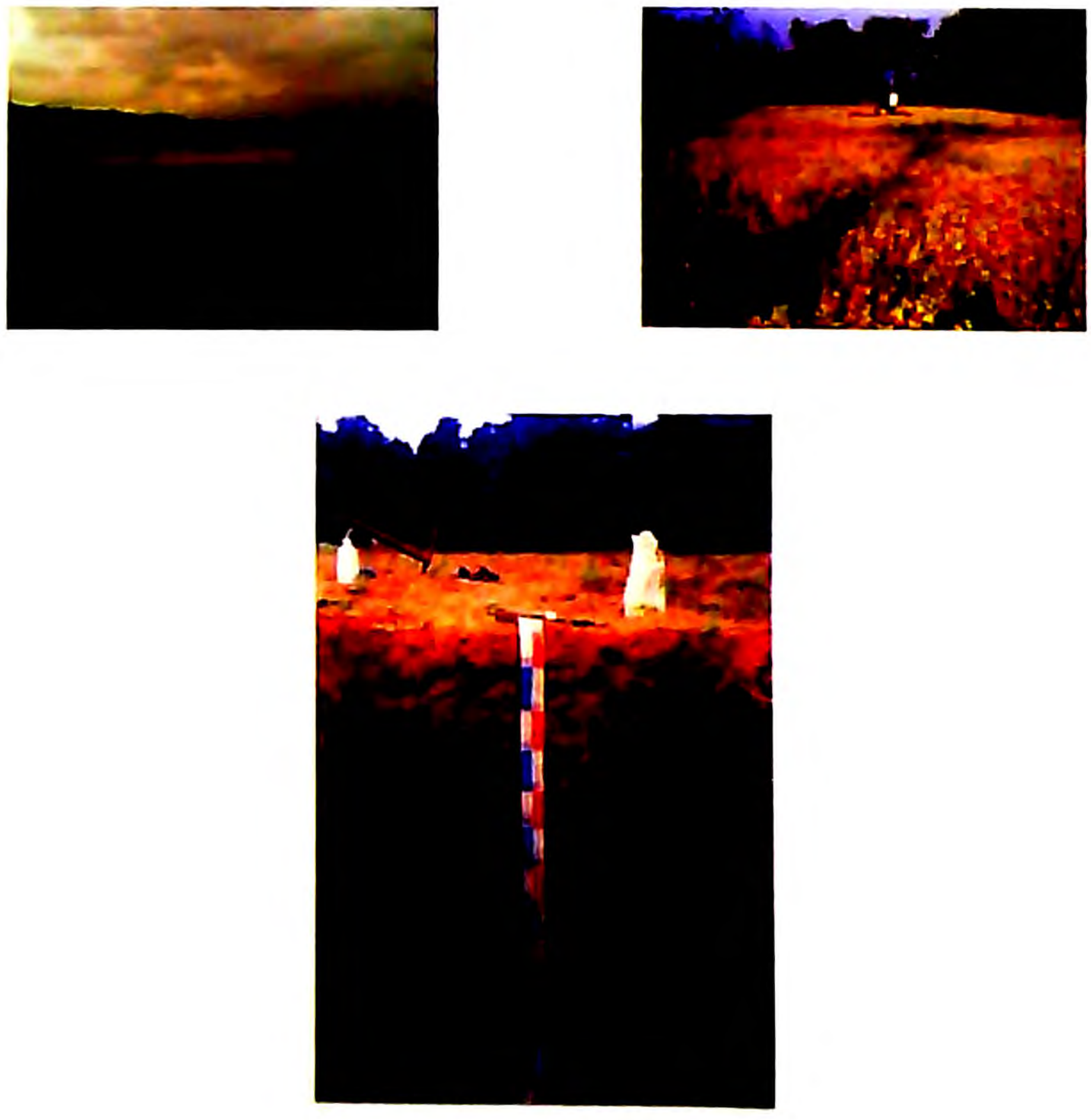

Fig. 3.19 Land and soils ofAgro-ecological unit X

The undulating uplands with rolling lands, low hills and valleys experiencing humid climate has given rise to highly weathered soils. The soils of the uplands are deep and very deep, reddish brown, fine textured and often gravelly. They have moderate subangular blocky structure. Soil reaction is strongly acid or extremely acid. The cation exchange capacity and base saturation are extremely low.

The soils of the valleys too are very deep, brown and fine textured. The strongly acid soils have low cation exchange capacity and base saturation.

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix XI.

The strongly acid reaction, fairly low organic matter content, and low cation exchange capacity and base saturation make these soils infertile. Regular addition of liming materials, organic matter and chemical fertilizers are unavoidable in this tract. The uplands are best devoted to plantation crops and low lands for rice. Extreme soil acidity and maintenance of continuously flooded conditions in rice paddies and consequent iron toxicity is the main reason for the low yield of rice in the area. Correction of soil acidity, organic matter addition and aerobic soil conditions (at least avoidance of continuous flooding) can substantially raise rice production.

The fairly long dry period warrants drip irrigation for plantation crops besides the addition of soil amendments, manures and fertilizers, for enhancing performance.

3.3 Southern Hilly Region

3.3.1 Agro-ecological unit XI

Agro-ecological unit XI comprises the hilly region in the south-eastern part of the district (Fig. 3.1).

The average annual rainfall is in the range 2000 to 2500 mm. Bulk of the precipitation is received from the south-west monsoon (Fig. 3.20, Appendix II). The mean annual daily temperature is 21.6 °C. December, January and February are the cold months. The mean daily temperature during the period is 20.9 °C, the minimum 16.3 °C and maximum, 25.5 °C. March, April and May are the hottest months with mean daily temperature of 23.9 °C, minimum 19.1 °C and maximum 28.7 °C. Climatically the area can be classified as humid (B4). There is a probability of moderate drought for a year in a block of ten years.

The growing period for annual crops starts from the last week of April (standard week 17) and continues till the first week of January of the following year (standard week 1). The total length of growing period is 252 days. The probability of a week being wet is high from the second week of June to the end of August (standard weeks 23 to 35) and from the first week of October to the second week of November (standard weeks 40 to 45). The probability of a week being dry is high for the whole of September (standard weeks 36 and 39).

The steeply sloping hilly terrain has fairly dense cover of forest (Fig. 3.21). Agricultural activity is confined to plantations of coffee, tea and cardamom.

The hilly terrain with steeply sloping lands has very deep, well-drained, dark reddish brown, organic matter rich, acid, fine-textured soils. The soils are moderately fertile.

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix XII.

This almost entirely forested region has little scope for agriculture except for large plantation estates.

3.3.2 Agro-ecological unit XII

The Nelliampathy hills in the southern part of the district constitute this unit (Fig. 3.1).

The hills rising abruptly to very high elevations from the plains cause orographic rains in the hills. That explains the high average annual rainfall in the range of 3000 to 3500 mm at Nelliampathy (Fig. 3.22, Appendix II). The mean annual daily temperature is 20.3 °C. December, January and February are the cold months. The mean daily temperature during the period is 20.9 °C, the minimum 16.3 °C and the maximum 25.5 °C. March, April and May are the hottest months with mean daily temperature of 23.9 °C, minimum 19.1 °C and maximum, 28.7 °C. Climatically the area can be classified as perhumid (A4). There is no probability of drought.

The growing season for annual crops starts from the last week of April (standard week 17) and continues till the end of February of the following year (standard week 9). The total

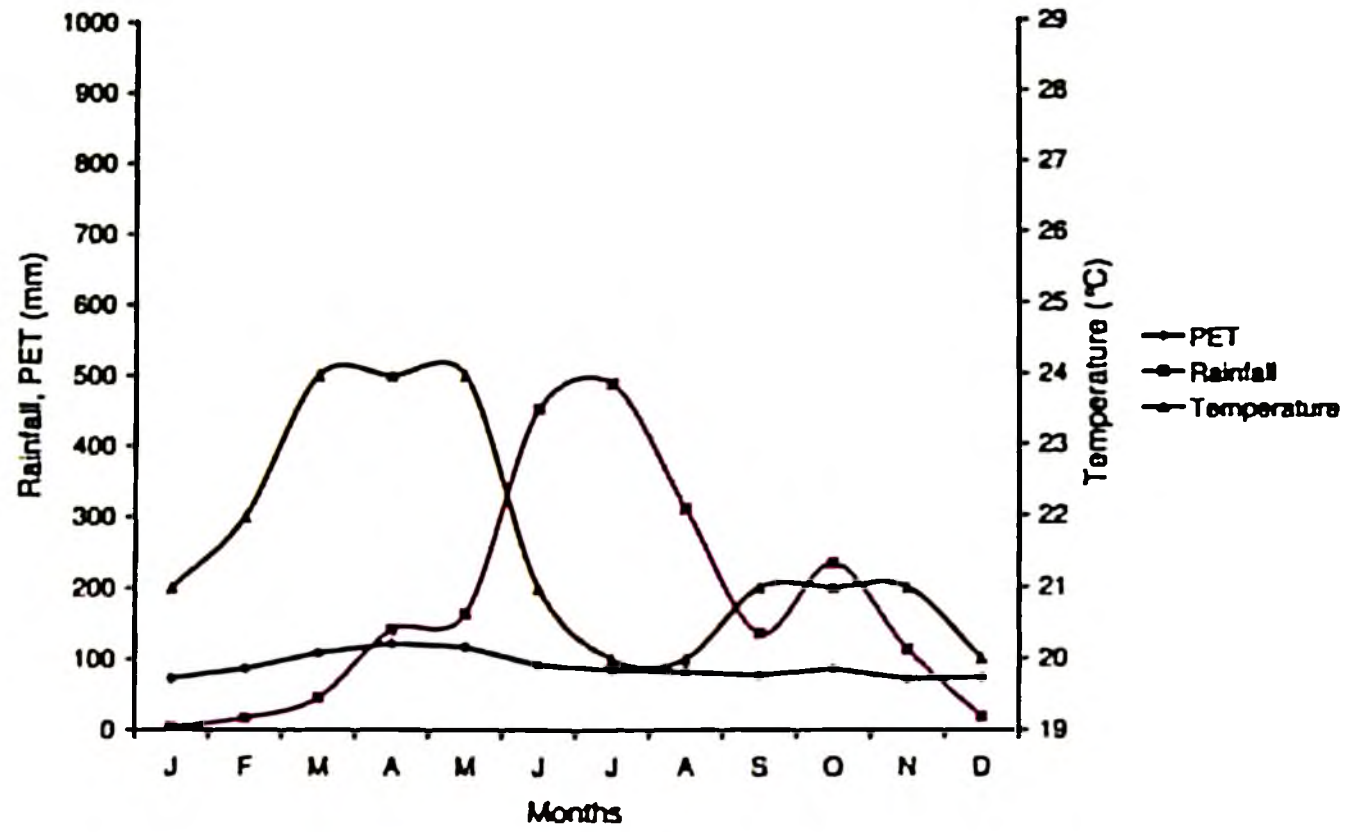

Fig. 3.20 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit XI

Fig. 3.21 Dense forest of Agro-ecological unit XI

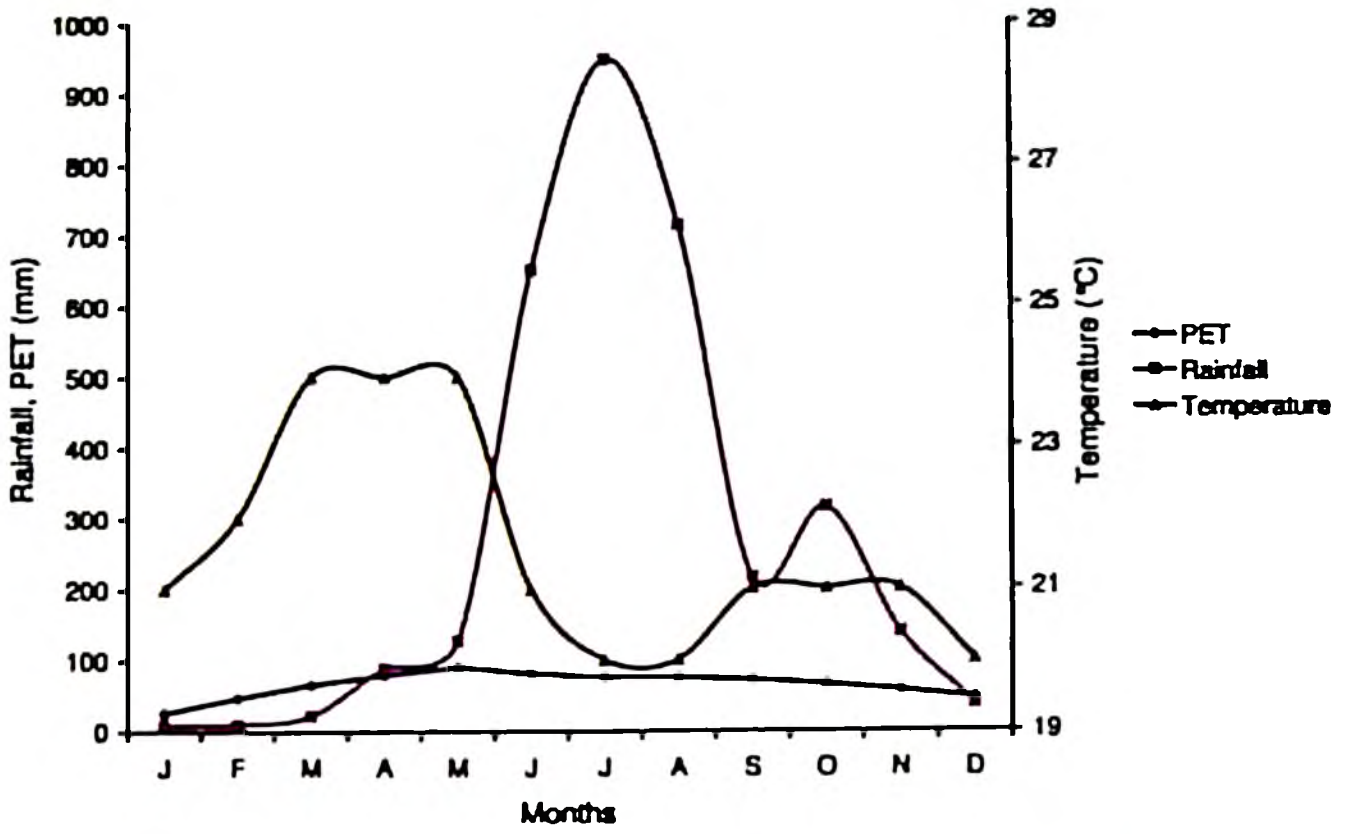

Fig. 3.22 Rainfall, temperature and potential evapo-transpiration in Agro-ecological unit XII

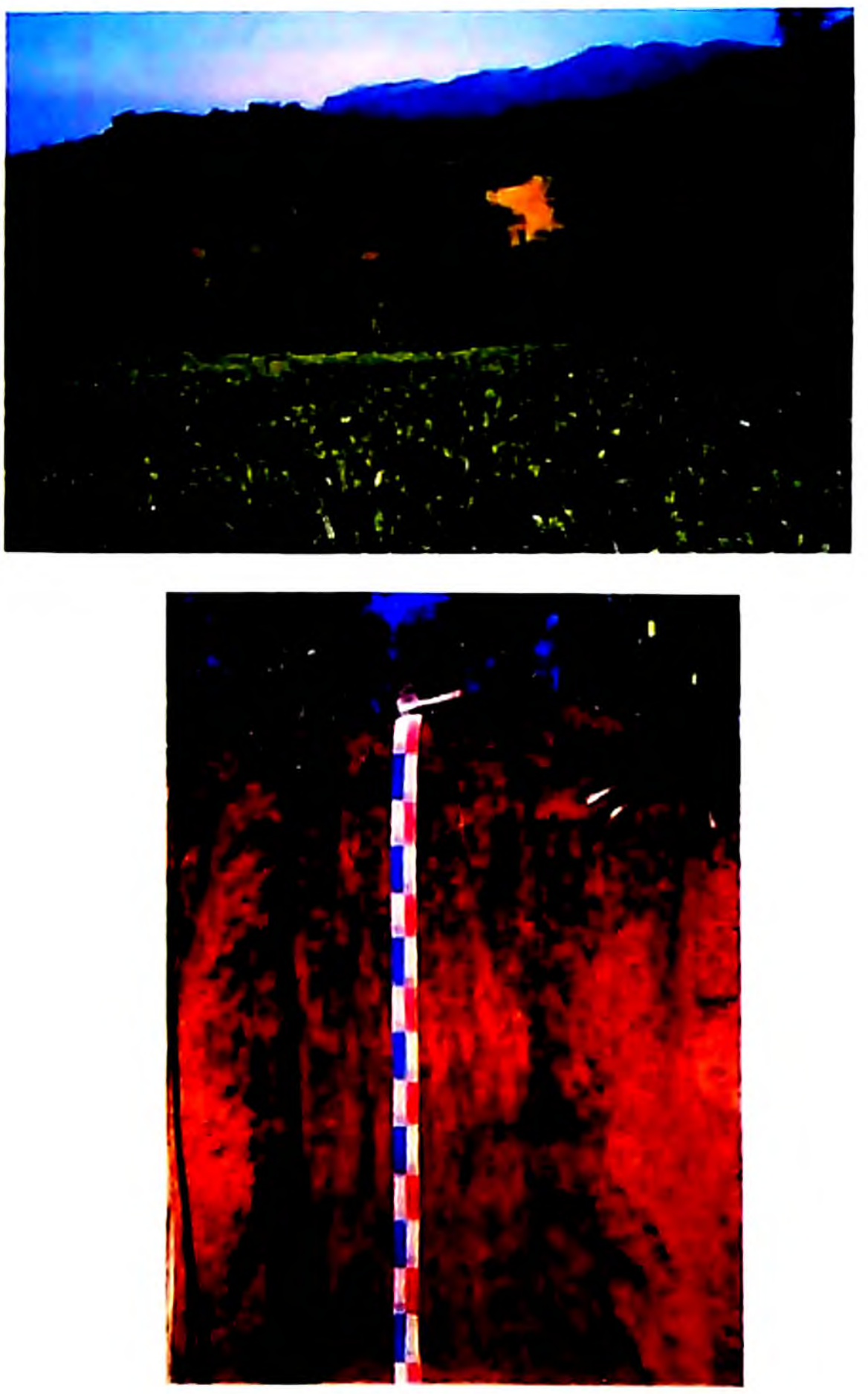

Fig. 3.23 Land and soils of Agro-ecological unit XII

length of growing period is 308 days. The probability of a week being wet is high from the first week of June to the first week of September (standard weeks 22 to 36) and from the last week of September to the second week of November (standard weeks 39 to 45) The second and third weeks of September (standard weeks 37 and 38) have high probability of week being dry.

The steeply sloping hilly terrain is covered by evergreen forests and plantations of coffee, tea and cardamom (Fig. 3.23).

The hilly terrain with steeply sloping lands have very deep, well drained, dark reddish brown, organic-matter-rich, fine-textured soils. The reaction of the soils is acidic. The soils are moderately fertile.

Description and analytical data pertaining to the pedons typifying the soils of the region are given in Appendix XII.

The hilly terrain with generally lower temperatures and perhumid climate is suitable for a variety of plantation, fruit and vegetable crops. The area is eminently suitable for high-value vegetable and fruit crops and commercial floriculture, taking advantage of the peculiar features of the climate.

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APPENDICES

APPENDIX I

Agro-ecological units, climatic data stations, data source and years for which data was available

Agro-ecological Unit	Climatic Data stations	Source	Years	Period
I	Mully	AHADS	5	1997, 1998, 1999, 2000, 2001
I	Vadakottathara	AHADS	5	1997, 1998,1999, 2002, 2003
I	Vattulakky	AHADS	5	1997, 1998, 1999, 2000, 2001
				Total No. of years = 7
II	Kavundikkal	CSWCRTIRC	11	1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996,1997
II	Goolikadavu	CSWCRTIRC	11	1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997
II	Kalkandi	CSWCRTIRC	9	1987, 1988, 1990, 1991, 1992, 1993, 1994, 1995, 1996,
II	Sholayur	AHADS	6	1998, 1999, 2000, 2001, 2002, 2003
				Total No. of years = 17
III	No Climatic station			
IV	Kallamala	AHADS	3	1999, 2000, 2001
				Total No. of years = 3
V	Karuvara	AHADS	3	1998, 1999, 2001
				Total No. of years = 3
VI	Shiruvani	ID	5	1994, 1995, 1996, 2000, 2001
VI	Kanjirapuzha	ID	10	1990, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000
				Total No. of years = 11

VII	Valayar	ID	14	1990, 1991, 1992, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004
VII	Eruthenpathy	DA farm	8	1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003
VII	Meenkara	ID	13	1990, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2003, 2004
VII	Chulliar	ID	7	1990, 1991, 1992, 2001, 2002, 2003, 2004
VII	Chittur	IMD	7	1972, 1973,1977, 1978, 1994, 1995, 1996
				Total No. of years = 19
VIII	Malampuzha	ID	11	1992, 1993, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003
VIII	Mangalam Dam	ID	11	1992, 1993, 1995, 1996, 1997, 1998, 2000, 2001, 2002, 2003, 2004
VIII	Alathur	IMD	22	1974, 1975, 1977, 1980, 1981, 1983, 1985, 1986, 1987, 1988, 1989, 1990, 1991, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002
VIII	Palakkad	IMD	18	1971, 1972, 1973, 1974, 1975, 1977, 1981, 1982, 1984, 1988, 1989, 1991, 1994, 1995, 1996, 1997, 1998, 1999
VIII	Pothundy	ID	9	1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004
				Total No. of years = 31
IX	Mannarkkad	IMD	9	1971, 1972, 1974, 1975, 1977, 1978,

				1994, 1995, 1996
IX	Ottapalam	IMD	8	1971, 1972, 1974, 1975, 1977, 1994, 1995, 1996
IX	Parli	IMD	8	1971, 1972, 1973, 1974, 1975, 1977, 1983, 1995
				Total No. of years = 11
X	Cherpulasserry	IMD	8	1971, 1972, 1974, 1975, 1977, 1979, 1980, 1981
X	Pattambi	IMD	7	1972, 1974, 1975, 1977, 1978, 1979, 1980
				Total No. of years = 9
XI	Parambikulam	ID	15	1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004
				Total No. of years = 15
XII	Nelliampathy	DA farm	11	1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003
				Total No. of years =11

IMD: Indian Meteorological Department
DA farm: Department of Agriculture farm
CSWCRTIRC: Central Soil and Water Conservation Research and Training Institute, Regional Centre
CWRDM: Centre for Water Resources Development and Management
AHADS: Attapadi Hill Area Development Society
ID: Irrigation Department

APPENDIX II Climatic Analysis

Average monthly, pre-monsoon, SW monsoon, NE monsoon rainfall for 28 stations of Palakkad

AU	Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Premon.	SW Mon.	NE Mon.	Total	PET
I	Mully	6.5	9.1	8.7	98.0	24.0	20.8	48.8	52.9	65.7	260.4	277.9	137.9	151.2	183.2	676.3	**1011**	1067
I	Vadakottathara	0.0	6.3	28.1	36.2	41.1	36.5	58.0	22.7	27.5	269.5	242.3	64.2	113.8	142.6	575.9	**832**	1067
I	Vattulakky	1.4	7.7	14.1	47.1	24.9	30.0	48.7	40.0	79.8	170.3	188.8	71.0	97.1	196.5	430.1	**724**	1067
	Mean	**2.63**	**7.70**	**16.97**	**60.43**	**30.00**	**29.10**	**51.83**	**38.53**	**57.67**	**233.40**	**236.33**	**91.03**	**120.70**	**174.10**	**560.77**	**856**	**1067**
II	Kavundikal	15.8	4.2	27.0	49.2	117.8	101.5	118.0	73.4	43.7	276.3	213.3	52.4	218.3	332.3	542.0	**1093**	1067
II	Goolikadavu	17.3	4.9	33.5	64.8	129.3	141.8	142.3	103.6	65.2	316.5	239.6	61.4	255.4	447.2	617.5	**1320**	1067
II	Kalkandi	23.8	4.9	45.3	105.9	173.9	74.6	80.9	57.0	70.8	381.3	308.3	88.6	357.6	279.6	778.2	**1415**	1067
II	Sholayur	0.8	15.4	48.4	68.1	56.3	163.6	160.1	101.6	42.7	311.9	236.5	79.0	194.8	462.3	627.4	**1285**	1067
	Mean	**14.43**	**7.35**	**38.55**	**72.00**	**119.33**	**120.38**	**125.33**	**83.90**	**55.60**	**321.50**	**249.43**	**70.35**	**256.53**	**380.35**	**641.28**	**1278**	1067
III	No data																	
IV	Kallamalla	0.0	6.3	0.0	124.8	166.2	525.5	490.5	307.7	118.2	427.2	126.0	3.3	306.7	**1432.5**	556.4	**2296**	1067
V	Karuvara	0.0	0.3	0.0	95.9	169.6	505.0	561.2	379.6	218.3	536.2	286.2	21.3	272.6	**1657.3**	843.6	**2774**	1067
VI	Shiruvani	9.8	11.2	2.1	85.5	118.6	778.5	844.5	405.0	310.9	299.7	191.0	55.3	249.8	2316.2	546.0	**3112**	1067
VI	Kanjirapuzha	2.6	4.4	14.7	145.3	162.5	612.8	801.8	396.9	302.9	515.9	183.3	28.7	354.0	2089.8	727.9	**3172**	1067
	Mean	**6.20**	**7.80**	**8.40**	**115.40**	**140.55**	**695.65**	**823.15**	**400.95**	**306.90**	**407.80**	**187.15**	**42.00**	**301.90**	**2203.00**	**636.95**	**3142**	**1067**
VII	Valayar	18.5	0.9	11.6	30.9	41.4	223.8	283.5	190.0	56.9	142.9	114.7	14.3	108.5	749.1	271.9	**1130**	1726

VII	Eruthenpathy	0.0	7.9	23.5	56.6	72.9	211.8	296.2	214.8	47.6	163.3	124.4	42.5	165.2	766.0	330.2	**1261**	1726
VII	Meenkara	4.8	17.4	26.2	42.3	65.9	272.1	319.4	225.3	66.4	203.9	123.3	23.0	162.5	877.3	350.1	**1390**	1726
VII	Chulliar	2.2	8.1	32.2	31.6	83.4	245.4	314.6	251.9	45.3	120.1	95.6	1.8	165.1	849.6	217.4	**1232**	1726
VII	Chittur	0.3	4.7	4.4	52.4	71.6	282.0	480.3	236.5	96.6	106.7	91.7	22.3	144.0	1084.7	220.7	**1449**	1726
	Mean	**5.16**	**7.80**	**19.58**	**42.76**	**67.04**	**247.02**	**338.80**	**223.70**	**62.56**	**147.38**	**109.94**	**20.78**	**149.06**	**865.34**	**278.06**	**1292**	**1726**
VIII	Malampuzha	2.9	2.8	20.5	62.9	93.8	326.7	448.0	346.1	158.2	250.4	121.2	13.2	192.4	1269.4	384.8	**1847**	1726
VIII	Mangalam	3.7	7.8	12.6	73.6	117.1	415.3	469.2	373.3	131.5	203.0	96.8	18.7	221.6	1382.5	318.4	**1923**	1726
VIII	Alathur	2.7	2.7	12.0	67.4	114.5	408.8	474.1	312.5	146.5	185.0	108.7	17.2	214.8	1326.4	310.9	**1852**	1726
VIII	Palghat	2.6	2.9	26.0	80.9	177.1	434.0	535.3	325.7	182.7	190.3	101.0	17.6	305.8	1461.5	309.0	**2076**	1726
VIII	Pothundy	1.9	5.5	13.0	79.0	121.4	415.6	514.5	439.2	131.4	238.3	114.9	20.7	232.9	1488.5	373.9	**2095**	1726
	Mean	**2.76**	**4.34**	**16.82**	**72.76**	**124.78**	**400.08**	**488.22**	**359.36**	**150.06**	**213.40**	**108.52**	**17.48**	**233.50**	**1385.66**	**339.40**	**1959**	**1726**
IX	Mannarkkad	3.5	9.7	26.0	109.8	152.8	381.8	613.2	386.9	216.4	361.9	174.3	29.5	324.0	1576.1	565.7	**2466**	1726
IX	Ottapalam	0.9	0.8	17.7	113.7	176.1	533.6	645.8	368.3	232.6	254.5	118.4	25.6	329.9	1759.4	398.5	**2488**	1726
IX	Parli	0.0	1.5	9.6	54.9	88.9	377.3	704.5	397.3	167.2	166.2	39.6	18.1	161.9	1639.4	223.9	**2025**	1726
	Mean	**1.47**	**4.00**	**17.77**	**92.80**	**139.27**	**430.90**	**654.50**	**384.17**	**205.40**	**260.87**	**110.77**	**24.40**	**271.93**	**1658.30**	**396.03**	**2326**	**1726**
X	Cherpulasseri	0.0	1.3	21.2	84.1	183.6	648.8	712.6	464.9	259.9	263.9	166.2	30.2	322.9	2053.4	460.3	**2837**	1726
X	Pattambi	0.1	2.6	5.0	46.5	194.6	598.6	704.5	436.3	222.7	288.6	211.5	32.9	282.7	1928.2	533.0	**2744**	1726
	Mean	**0.05**	**1.95**	**13.10**	**65.30**	**189.10**	**623.70**	**708.55**	**450.60**	**241.30**	**276.25**	**188.85**	**31.55**	**302.80**	**1990.80**	**496.65**	**2790**	**1726**
XI	Parambikulam	**4.3**	**16.6**	**44.9**	**141.6**	**163.9**	**452.7**	**487.8**	**311.3**	**135.6**	**233.4**	**112.5**	**17.8**	**386.2**	**1372.6**	**363.7**	**2123**	**1067**
XII	Nelliampathi	**8.5**	**9.3**	**21.4**	**88.5**	**126.9**	**650.9**	**948.2**	**712.4**	**214.8**	**313.3**	**137.3**	**37.0**	**271.2**	**2509.8**	**487.5**	**3269**	**775**

APPENDIX III

Major soils of agro-ecological unit I

The hill slopes of agro-ecological unit I is mostly covered by shallow well-drained gravelly clay soils formed on weathered granite-gneiss.

A pedon excavated in Kottathara village, Mannarkkad taluk, Palakkad district (11° 07′ N latitude and 76° 40′ E longitude) is presented below along with analytical data.

A	0-12 cm	Yellowish red (5YR 5/6 D & M) gravelly clay; moderate medium granular structure; very hard, friable, sticky and plastic; 40 per cent fine and coarse gravel; common very fine roots; strongly acid (pH 5.3); clear smooth boundary.
Bt	12-40 cm	Dark reddish brown (2.5YR 3/4 M) gravelly clay; moderate medium subangular blocky structure; friable, very sticky and very plastic; 60 per cent fine and coarse gravel; thick clay cutans; slightly alkaline (pH 7.8); gradual smooth boundary.
C	40-60 cm	Weathered gneiss

Classification: Clayey-skeletal, mixed, isohyperthermic, Lithic Rhodustalf

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-18	A	49.8	23.8	26.4	40	gc	5.3	0.92
18-33	Bt	35.6	26.7	37.7	60	gc	7.8	0.79

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-18	11.68	1.66	0.16	0.54	14.04	10.5	100
18-33	16.51	1.78	0.24	0.21	18.70	16.0	100

Soils of the narrow valleys of the unit are moderately deep with gravelly sandy clay loam surface soil and subsoil layers. Formed in colluvial deposits of granite-gneiss origin they are well-drained. A profile located in Kottathara village, Mannarkkad taluk, Palakkad district at 11°07′ N latitude and 76°41′ E longitude is described below.

A	0-18 cm	Dark reddish brown (5YR 3/3 M) gravelly sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; 40 per cent fine and coarse gravel; common very fine and medium lime concretions; violent effervescence with dilute HCl; many very fine roots; moderately alkaline (pH 8.1); clear smooth boundary.
Bw1	18-33 cm	Dark reddish brown (5YR 3/3 M) gravelly sandy clay loam; weak medium subangular blocky structure; friable, sticky and plastic; 40 per cent fine and coarse gravel; common fine and medium lime concretions; violent effervescence with dilute HCl; many very fine roots; moderately alkaline (pH 8.3); clear smooth boundary.
Bw2	33-65 cm	Dark reddish brown (5YR 3/3 M) gravelly sandy clay loam; weak medium subangular blocky structure; friable, sticky and plastic; 60 per cent fine and coarse gravel; common very fine and medium lime concretions; violent effervescence with dilute HCl; common very fine roots; moderately alkaline (pH 8.3); clear smooth boundary.
Bw3	65-85 cm	Yellowish red (5YR 4/6 M) gravelly sandy clay loam; weak medium subangular blocky structure; friable, sticky and plastic; common medium lime concretions; violent effervescence with dilute HCl; few very fine roots; moderately alkaline (pH 8.4).
Ck	85-110 cm	Parent material with lime nodules.

Classification: Loamy-skeletal, mixed, isohyperthermic, Typic Ustropept

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-18	A	48.7	12.2	22.4	40	gscl	8.1	1.64
18-33	Bw1	51.9	15.1	21.4	40	gscl	8.3	1.25
33-65	Bw2	47.7	16.7	34.0	60	gscl	8.3	1.32
65-85	Bw3	46.3	18.0	22.3	40	gscl	8.4	0.97

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-18	31.78	1.84	0.05	1.50	35.17	12.2	100
18-33	34.49	1.64	0.06	0.66	36.85	14.0	100
33-65	30.28	1.46	0.07	0.46	32.27	13.1	100
65-85	38.98	1.33	0.08	0.33	40.72	12.5	100

APPENDIX IV

Major soils of agro-ecological unit II

The slopes of the low hills in agro-ecological unit II have deep, well-drained, dark brown, sandy loam soils formed from weathered granite-gneiss.

A soil profile was exposed in the Agali village, Mannarkkad taluk, Palakkad district (11° [illegible]' N latitude and 76° 38' E longitude) to study and sample the soils. The description and morphological and physico-chemical properties follow

A	0- 7 cm	Very dark grey brown (10YR 3/2 M) sandy loam; 10 per cent fine gravel; moderate medium subangular blocky structure; firm, slightly sticky and slightly plastic; many very fine and fine roots; slightly acid (pH 6.2); clear smooth boundary
AB	7-30 cm	Dark brown (7.5YR 4/3 M) sandy loam; 10 per cent fine gravel; weak medium subangular blocky structure; friable, slightly sticky and slightly plastic; common very fine and few medium and coarse roots; neutral (pH 6.8); clear smooth boundary
Bt1	30-70 cm	Dark reddish brown (5YR 3/4 M) sandy clay loam; 10 per cent fine gravel; moderate medium subangular blocky structure; firm, sticky and plastic; common very fine and medium roots; neutral (pH 6.7); gradual wavy boundary
Bt2	70- 90 cm	Dark brown (7.5YR 3/2 M) gravelly sandy clay loam; 20 per cent fine gravel; moderate medium subangular blocky structure; firm, sticky and plastic; common very fine roots; slightly acid (pH 6.5); gradual wavy boundary
Bt3	90- 40 cm	Dark red (2.5YR 3/2 M) sandy clay loam; 10 per cent fine gravel; strong coarse subangular blocky structure; firm, sticky and plastic; thick patchy cutans; common very fine roots; neutral (pH 7.0); gradual wavy boundary
Bw	140-165 cm	Yellowish red (5YR 4/6 M) sandy loam; less than 10 per cent fine gravel; moderate medium subangular blocky structure; firm, sticky and plastic; thin patchy cutans; neutral (pH 7.0);
C	165 cm	Weathered rock

Classification: Fine-loamy, mixed, subhyperthermic, Typic Haplustalf

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-13	A	60.0	26.1	13.9	10	sl	6.3	1.10
13-30	AB	72.5	19.5	8.0	10	sl	6.6	0.41
30-73	BA	50.6	26.6	22.9	10	scl	6.67	1.09
73-100	Bt1	48.2	26.2	25.5	20	gscl	6.5	1.53
100-140	Bt2	51.4	27.3	21.4	10	scl	7.0	0.41
140-165	Bt3	56.1	25.4	18.5	10	sl	7.0	0.33

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-13	7.55	3.21	0.06	0.11	10.93	10.3	100
13-30	6.99	2.65	0.05	0.08	9.77	9.7	100
30-73	9.89	3.93	0.10	0.11	14.03	13.7	100
73-100	9.58	3.69	0.10	0.18	13.55	13.9	100
100-140	9.15	3.73	0.12	0.07	13.07	10.7	100
140-165	9.06	3.24	0.06	0.06	12.42	10.4	100

The gently sloping valleys of agro-ecological unit II have for the most part very deep, well-drained, gravelly sandy clay loam soils. They are formed from alluvial and colluvial deposits of granite-gneiss origin.

In the following sections are presented the morphological and physico-chemical properties of a pedon exposed in Agali village, Mannarkkad taluk, Palakkad district (11°06′ N latitude and 77°30′ E longitude).

Ap	0-20 cm	Dark reddish brown (5YR 3/3 M) gravelly sandy clay loam; 20 per cent fine and coarse gravel; moderate medium subangular blocky structure; friable, sticky and plastic; few fine iron concretions; many very fine roots; neutral (pH 6.7); clear smooth boundary.
AB	20-38 cm	Dark reddish brown (5YR 2.5/2 M) gravelly sandy clay loam; 15 per cent fine and coarse gravel; weak medium subangular blocky structure; friable, sticky and plastic; many medium and very fine roots; slightly acid (pH 6.5); clear smooth boundary.
Bt1	38-64 cm	Dark reddish brown (5YR 3/4 M) gravelly sandy clay; 15 per cent fine and coarse gravel; strong medium subangular blocky structure; friable, very sticky and very plastic; thin patchy clay cutans; few fine and medium roots; neutral (pH 6.7); gradual smooth boundary.
Bt2	64-84 cm	Red (2.5YR 4/6 M) gravelly sandy clay loam; 50 per cent fine and coarse gravel; strong medium subangular blocky structure; friable, very sticky and very plastic; thin patchy clay cutans; few fine roots; slightly alkaline (pH 7.4); gradual wavy boundary.
Bt3	84-134	Dark red (2.5YR 3/6 M) sandy clay; strong medium subangular blocky structure; firm, very sticky and very plastic; 15 per cent fine and coarse gravel; thick patchy clay cutans; few fine roots; pH 7.5; gradual smooth boundary.
Bt4	130-200	Dark red (2.5YR 3/6 M) clay loam; strong medium subangular blocky structure; firm, very sticky and very plastic; 10 per cent fine and coarse gravel; thick patchy cutans; few fine roots; neutral (pH 7.2).

Classification: Fine, mixed, isohyperthermic, Pachic Argiustoll

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-20	Ap	59.2	17.4	23.4	20	gscl	6.7	1.00
20-38	AB	52.8	19.6	27.6	15	gscl	6.5	1.39
38-64	Bt1	46.8	16.3	36.9	15	gsc	6.7	0.82
64-84	Bt2	47.6	18.2	34.2	50	gscl	7.4	0.50
84-130	Bt3	45.2	10.9	44.0	15	gsc	7.5	0.34
130-200	Bt4	44.4	30.6	35.0	10	gcl	7.2	0.25

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-20	7.12	2.35	0.04	0.34	9.85	10.2	97
20-38	9.97	3.39	0.06	0.32	13.74	13.5	100
38-64	10.10	3.73	0.05	0.16	14.04	12.5	100
64-84	9.64	4.04	0.20	0.14	14.02	11.3	100
84-130	10.21	4.75	0.29	0.17	15.42	12.1	100
130-200	9.72	4.87	0.20	0.12	14.91	11.9	100

APPENDIX V

Major soils of agro-ecological unit IV

Deep well-drained, clay soils were observed on hill slopes of agro-ecological unit IV. The soil described below, formed on gneissic rock was studied at Jellippara, Attapadi block, Mannarkkad taluk, Palakkad district.

A11	0-2 cm	Very dark reddish brown (2.5YR 3/1 M) clay; crumb structure; friable, non-sticky and non-plastic; many fine pores; many fine, medium and coarse roots; moderate earthworm and faunal activity; moderately acid (pH 6.0); clear smooth boundary.
A12	2-9 cm	Dark reddish brown (2.5YR 3/3 M) clay; weak fine granular structure; friable, non-sticky and non-plastic; many fine pores; many fine and medium roots; moderate earthworm and faunal activity; slightly acid (pH 6.2); clear smooth boundary.
A13	9-32 cm	Dark reddish brown (2.5YR 3/3 M) clay; weak fine granular structure; friable, non-sticky and non-plastic; many fine pores; many fine and medium roots; slightly acid (pH 6.1); clear smooth boundary.
Bw	32-51 cm	Dark reddish brown (2.5YR 3/3 M) clay; weak fine subangular blocky structure; friable, slightly sticky and slightly plastic; common fine pores; common fine and medium roots; slightly acid (pH 6.3); gradual smooth boundary.
Bt1	51-89 cm	Dark reddish brown (2.5YR 3/3 M) clay; moderate medium subangular blocky structure; friable, sticky and plastic; common fine pores; few fine roots; slightly acid (pH 6.2); thin patchy clay cutans; gradual smooth boundary.
Bt2	89-102 cm	Dark red (2.5YR 3/5 M) clay; moderate medium subangular blocky structure; friable, sticky and plastic; common fine pores; very few fine roots; slightly acid (pH 6.1); thin patchy clay cutans.

Classification: Fine, mixed, isohyperthermic, Typic Haplustalf

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-2	A11	19.12	21.57	59.31	0	c	6.0	3.21
2-9	A12	26.27	20.61	53.12	2	c	6.2	2.79
9-32	A13	26.99	24.10	48.91	3	c	6.1	2.08
32-51	Bw	29.37	21.32	49.31	2	c	6.3	1.25
51-89	Bt1	24.64	11.69	53.67	0	c	6.2	0.76
89-102	Bt2	20.22	27.29	52.49	0	c	6.1	0.31

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-2	15.0	6.5	0.2	0.5	22.2	22.4	99
2-9	13.0	6.0	0.1	0.4	19.5	19.6	99
9-32	12.5	5.5	0.2	0.2	18.4	18.4	100
32-51	12.0	6.5	0.2	0.2	18.9	18.9	100
51-89	13.5	4.5	0.1	0.1	18.2	18.2	100
89-102	16.5	5.0	0.2	0.2	21.9	21.9	100

APPENDIX VI

Major soils of agro-ecological unit V

The forested hills of agro-ecological unit V have very deep, well-drained, clay loam and clay soils developed from weathered charnockite rocks.

A profile was exposed in Karivara, Mannarkkad taluk, Palakkad (11° 14′ N latitude; 76° 31′ E longitude) and studied for morphological, physical and chemical properties.

A	0-26 cm	Very dark brown (10YR 2/2 M) silty clay loam; weak medium subangular blocky structure; friable, slightly sticky and slightly plastic; many fine and medium roots; very strongly acid (pH 4.8); clear smooth boundary.
AB	26-46 cm	Very dark brown (10YR 2/2 M) clay loam; moderate medium subangular blocky structure; friable, slightly sticky and slightly plastic; many fine and medium roots; very strongly acid (pH.4.7); clear smooth boundary.
Bt	46-85 cm	Reddish brown (2.5YR 5/4 M) clay; moderate medium subangular blocky structure; friable, sticky and plastic; thin patchy cutans; common fine and medium roots; very strongly acid (pH 5.0); clear smooth boundary.
Bt2	85-125 cm	Dark reddish brown (2.5YR 3/4 M) clay moderate medium subangular blocky structure; friable, sticky and plastic; thin patchy cutans, common fine and medium roots; very strongly acid (pH 4.9); clear smooth boundary.
Bt3	125-161 cm	Dark red (2.5YR 3/6 M) clay; moderate medium subangular blocky structure; friable, sticky and plastic; thin patchy cutans, few fine and medium roots; very strongly acid (pH 4.9); clear smooth boundary.
Bt4	161-182 cm	Dark red (2.5YR 3/6 M) clay; moderate medium subangular blocky structure; friable, sticky and plastic; thin patchy cutans, few fine roots; strongly acid (pH 5.1).

Classification: Clayey, mixed, isohyperthermic, UStic Palehumult

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-26	A	34.0	26.0	40.0	0	sicl	4.8	4.03
26-46	AB	32.4	22.1	45.5	0	cl	4.7	2.54
46-85	Bt1	29.6	21.2	49.2	0	c	5.0	1.71
85-125	Bt2	20.6	19.2	60.2	0	c	4.9	0.96
125-161	Bt3	20.9	18.5	60.6	0	c	4.9	0.82
161-182	Bt4	22.1	21.3	56.6	0	c	5.1	0.67

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-26	6.17	2.19	0.06	1.35	9.77	18.3	53
26-46	3.41	1.62	0.05	0.64	5.72	15.1	38
46-85	2.19	1.25	0.05	0.57	4.06	11.6	35
85-125	1.64	1.32	0.03	0.46	3.51	10.4	33
125-161	1.33	1.42	0.04	0.41	3.20	10.5	30
161-182	1.58	1.40	0.08	0.34	3.40	9.2	37

APPENDIX VII

Major soils of agro-ecological unit VI

The densely forested hilly terrain of agro-ecological unit VI has very deep, well-drained, dark reddish brown, acid soils. The surface soils have sandy clay loam texture and weak medium subangular blocky structure; subsoil layers are clay with moderate and weak medium subangular blocky structure.

Data pertaining to a typical pedon studied in Kongad village, Ottapalam taluk, Palakkad district (10° 52′ 50″ N latitude and 76° 31′ 55″ E longitude) are presented below.

A	0-17 cm	Dark reddish brown (2.5YR 3/4) sandy clay loam; 5 per cent fine gravel; weak medium subangular blocky structure; friable, sticky and plastic; common coarse roots; common fine pores; very strongly acid (pH 4.7); clear smooth boundary.
Bt1	17-43 cm	Dark red (2.5YR 3/6) clay loam; 5 per cent fine gravel; moderate medium subangular blocky structure; friable, sticky and plastic; common fine roots; many fine pores; patchy thin clay skins; very strongly acid (pH 4.8); clear smooth boundary.
Bt2	43-80 cm	Dark red (2.5YR 3/6) and strong brown (7.5YR 5/6) variegated clay; 5 per cent fine gravel; weak medium subangular blocky structure; friable; sticky and plastic; few very fine roots; many very fine pore; patchy thin clay skins; very strongly acid (pH 4.7); gradual smooth boundary.
Bt3	80-155 cm	Red (2.5YR 4/6) and strong brown (7.5YR 5/6) variegated clay; 5 per cent fine gravel; weak medium subangular blocky structure; friable, sticky and plastic; few very fine roots; many very fine pores; patchy thin clay skins; very strongly acid (pH 4.9).

Classification: Clayey, kaolinitic, isohyperthermic, Typic Kandiustult

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-17	A	56.4	15.7	27.9	0	scl	4.7	1.24
17-43	Bt1	44.4	19.0	36.6	5	cl	4.8	0.55
43-80	Bt2	29.3	17.4	53.3	5	c	4.7	0.35
80-155	Bt3	28.4	16.7	54.9	5	c	4.9	0.26

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-17	0.80	0.70	0.10	0.10	1.70	4.9	35
17-43	1.00	0.60	0.10	0.10	1.80	4.9	37
43-80	1.00	0.60	0.10	0.10	1.80	4.9	37
80-155	0.80	0.40	0.10	0.10	1.40	4.4	32

APPENDIX VIII

Major soils of agro-ecological unit VII

Uplands of agro-ecological unit VII mostly have soils of Ozhalapathy series. Ozhalapathy soils are deep with sandy clay surface soil and sandy clay loam, gravelly sandy clay and clay subsoil layers. They are well-drained and moderately permeable. These soils are formed on granite. The slope of the land ranges from 3 to 5 per cent.

The typical pedon of Ozhalapathy sandy clay is located on gently sloping uplands of Palaniyarpalem village of Kozhinjampara panchayat, Chittur taluk, Palakkad district.

Ap	0-14 cm	Dark reddish brown (5YR 3/3) sandy clay; weak medium subangular blocky structure; friable, sticky and plastic; many fine and common medium roots; few medium pores; slightly alkaline (pH 7.5); clear smooth boundary.
Bt1	14-36 cm	Dark reddish brown (5YR 3/3) sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; moderately thick patchy clay cutans; many fine and common medium roots; very few coarse pores; few coarse lime nodules; neutral (pH 7.1); gradual smooth boundary.
Bt2	36-70 cm	Dark reddish brown (5YR 3/4) clay; moderate medium subangular blocky structure; friable, sticky and plastic; moderately thick patchy clay cutans; common medium roots; few coarse pores; few fine lime nodules; neutral (pH 7.3); gradual smooth boundary.
Bt3	70-110 cm	Dark reddish brown (2.5YR 3/4) clay; moderate medium subangular blocky structure; friable; sticky and plastic; moderately thick patchy clay cutans; many coarse roots; few coarse pores; few coarse lime nodules; neutral (pH 7.1); gradual smooth boundary.
Bt4	110-141 cm	Dark reddish brown (2.5YR 3/4) gravelly sandy clay; 65 per cent fine gravel; strong medium subangular blocky structure; friable, sticky and plastic; moderately thick patchy clay cutans; few fine roots; few coarse pores; few coarse lime nodules; neutral (pH 7.1); clear smooth boundary.
Cr	141 cm	Weathered granite.

Classification: Clayey-skeletal, mixed, isohyperthermic, Typic Haplustalf

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-14	Ap	53.9	8.9	37.2	10	sc	7.5	0.75
14-36	Bt1	65.5	7.2	27.3	10	scl	7.1	0.36
36-70	Bt2	44.1	6.8	49.1	5	c	7.3	0.40
70-110	Bt3	44.6	6.4	49.0	10	c	7.1	0.22
110-141	Bt4	47.9	5.2	46.9	65	gsc	7.1	0.16

Depth cm	Exchangeable bases		CEC (NH_4OAc)	Base Satn. %
	Na	K		
	cmol (+) kg^{-1} soil			
0-14	0.47	0.59	16.3	100
14-36	0.50	0.18	11.8	100
36-70	0.88	0.22	18.3	100
70-110	1.18	0.19	18.4	100
110-141	1.53	0.19	18.4	100

Soils belonging to Annuppur series cover most of the very gently sloping footslopes in agro-ecological unit VII. Annuppur soils have clay surface soil and clay and gravelly clay subsoil layers. These soils are moderately well-drained and slightly permeable. They are formed on gneiss. The slope of the land ranges from 1 to 3 per cent.

The typical pedon of Anuppur clay is located on gently sloping uplands of Ozhalapathy village of Vadakarapathy panchayat, Chittur taluk, Palakkad district.

Ap	0-18 cm	Very dark brown (10YR 2/2) clay; moderate medium subangular blocky structure; slightly hard, friable, very sticky and very plastic; common fine roots; common fine pores; few fine lime nodules; strong effervescence; moderately alkaline (pH 7.9); clear smooth boundary.
Bss1	18-53 cm	Very dark brown (10YR 2/2) gravelly clay; 20 per cent fine gravel; strong medium and coarse subangular/angular blocky structure; very sticky and very plastic; intersecting slickensides; few fine and few very fine roots; few fine lime nodules; violent effervescence; moderately alkaline (pH 7.9); gradual smooth boundary.
Bss2	53-70 cm	Very dark brown (10YR 2/2) gravelly clay; 15 per cent fine gravel; strong medium and coarse subangular/angular blocky structure; very sticky and very plastic; intersecting slickensides; few fine and few very fine roots; common medium lime nodules; violent effervescence; moderately alkaline (pH 8.0); clear smooth boundary.
Bss3	70-93 cm	Very dark brown (10YR 3/2) gravelly clay; 25 per cent fine gravel; strong medium subangular blocky structure; very sticky and very plastic; intersecting slickensides; few very fine roots; common coarse lime nodules; strong effervescence; moderately alkaline (pH 7.9); clear smooth boundary.
Bss4	93-120 cm	Dark brown (7.5YR 3/2) clay; moderate medium subangular blocky structure; sticky and plastic; intersecting slickensides; few fine lime nodules; strong effervescence; moderately alkaline (pH 7.9); clear smooth boundary.
Bss5	120-151 cm	Dark brown (7.5YR 3/2) gravelly clay; 20 per cent fine gravel; moderate medium subangular blocky structure; sticky and plastic; intersecting slickensides; few fine lime nodules; strong effervescence; moderately alkaline (pH 7.9).

Classification: Very- fine, smectitic, isohyperthermic, Udic Haplustert

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-18	AP	19.6	18.6	61.8	7	c	7.9	1.31
18-53	Bss1	22.1	10.7	67.2	20	gc	7.9	0.96
53-70	Bss2	16.0	17.9	66.1	15	gc	8.0	0.92
70-93	Bss3	15.3	17.1	67.6	25	gc	7.9	0.84
93-120	Bss4	11.9	19.1	69.0	5	c	7.9	0.79
120-151	Bss5	12.2	19.0	68.8	20	gc	7.9	0.76

Depth cm	Exchangeable bases		CEC (NH_4OAc)	$CaCO_3$ Equivt.	Base Satn. %
	Na	K			
	cmol (+) kg^{-1} soil				
0-18	0.30	1.74	35.6	4	100
18-53	0.41	1.04	39.2	4	100
53-70	0.37	0.98	41.6	5	100
70-93	0.42	0.97	43.3	5	100
93-120	0.78	0.99	47.5	5	100
120-151	0.79	1.00	48.6	4	100

In the nearly level lowlands of agro-ecological unit VII the predominant soils belong to Vannamada series. Vannamada soils are very deep and have sandy clay surface soil and clay and sandy clay loam subsoil layers. They are moderately well-drained and slowly permeable. These soils are formed in alluvium. The slope of the land ranges from 0 to 1 per cent.

The typical pedon of Vannamada sandy clay is located on nearly level lowland in Attayampathy village of Vadakarapathy panchayat, Chittur taluk, Palakkad district.

Ap	0-21 cm	Very dark grayish brown (10YR 3/2 M) sandy clay; moderate medium subangular blocky structure; friable, sticky and plastic; many very fine and fine roots; common fine pores; strong effervescence; slightly alkaline (pH 7.8); clear smooth boundary.
Bw1	21-48 cm	Very dark brown (10YR 2/2) clay; strong medium subangular blocky structure; friable, sticky and plastic; pressure faces on peds; common very fine and fine roots; many fine pores; slight effervescence; slightly alkaline (pH 7.6); clear smooth boundary.
Bw2	48-79 cm	Black (10 YR 2/1) clay; strong medium subangular blocky structure; friable, sticky and plastic; pressure faces on peds; few very fine and fine roots; many fine pores; slight effervescence; neutral (pH 7.2); gradual smooth boundary.
Bw3	79-112 cm	Very dark brown (10 YR 2/2) sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; pressure faces on peds; few very fine roots; common fine pores; slight effervescence; neutral (pH 7.1); clear smooth boundary.
Bw4	112-150 cm	Dark brown (7.5YR 4/2) sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; common fine pores; slight effervescence; neutral (pH 7.2).

Classification: Fine, mixed, isohyperthermic, Vertic Epiaquept

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-21	Ap	45.8	13.7	40.5	10	sc	7.8	1.38
21-48	Bw1	44.4	14.0	41.6	Nil	c	7.6	1.00
48-79	Bw2	44.4	14.0	41.6	Nil	c	7.2	1.18
79-112	Bw3	58.7	9.7	31.6	Nil	scl	7.1	0.83
112-150	Bw4	60.8	8.0	31.2	Nil	scl	7.2	0.76

Depth cm	Exchangeable bases		CEC (NH_4OAc)	Base Satn. %
	Na	K		
	cmol (+) kg^{-1} soil			
0-21	0.11	0.58	28.5	100
21-48	0.11	0.32	27.3	100
48-79	0.12	0.27	18.4	100
79-112	0.18	0.26	20.1	100
112-150	0.24	0.26	17.5	100

APPENDIX IX

Major soils of agro-ecological unit VIII

The two kinds of soils of extensive occurrence in agro-ecological unit VIII belong to Karinganthode series in the uplands and Tolanur series in low lands.

Karinganthode series consists of very deep soils on moderately sloping uplands. Karinganthode soils have sandy clay loam surface soil and sandy clay and sandy clay loam subsoil layers. They are formed on granitic parent material and are well-drained. The slope of the land ranges from 5 to10 per cent.

The typical pedon of Karinganthode sandy clay loam is located on moderately sloping land in Kuthannur panchayat, Alathur taluk, Palakkad district.

Ap	0-19 cm	Dark reddish brown (5 YR 3/3 M) sandy clay loam; moderate medium subangular blocky structure; slightly hard, friable, sticky and plastic; many very fine and fine roots; many fine pores; strongly acid (pH 5.3); clear smooth boundary.
Bt1	19-48cm	Dark red (2.5YR 3/6 M) sandy clay; moderate medium subangular blocky structure; friable, sticky and plastic; many thick continuous cutans; common very fine and fine roots; many fine pores; very strongly acid (pH 4.9); clear smooth boundary.
Bt2	48-76 cm	Red (2.5YR 4/6 M) sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; many thick continuous cutans; common very fine and fine roots; many fine pores; very strongly acid (pH 4.8); clear smooth boundary.
Bt3	76-98 cm	Dark reddish brown (5YR 3/4 M) sandy clay; moderate medium subangular blocky structure; friable, sticky and plastic; many thick continuous cutans; few very fine and fine roots; many fine pores; gradual smooth boundary.
Bt4	98-125 cm	Dark reddish brown (5YR 3/3 M) sandy clay; moderate medium subangular blocky structure; friable, sticky and plastic; many thick continuous cutans; few very fine and fine roots; many fine pores; very strongly acid (pH 5.0); gradual smooth boundary.

Bt5	125-152 cm	Dark reddish brown (5YR 3/4 M) sandy clay; moderate medium subangular blocky structure; friable, sticky and plastic; many thick continuous cutans; many fine pores; very strongly acid (pH 5.0).

Classification: Fine, mixed, isohyperthermic, Ultic Paleustalf

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-19	Ap	55.5	11.0	33.5	0	scl	5.3	0.93
19-48	Bt1	51.7	11.9	36.4	0	sc	4.9	0.85
48-76	Bt2	56.0	10.3	33.7	0	scl	4.8	0.98
76-98	Bt3	53.1	9.8	37.1	0	sc	4.9	1.04
98-125	Bt4	49.9	10.8	39.3	0	sc	5.0	1.14
125-152	Bt5	52.5	8.9	38.6	0	sc	5.0	1.03

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-19	3.5	1.6	0.05	0.14	5.29	10.1	52
19-48	2.9	1.5	0.05	0.11	4.56	10.2	45
48-76	2.0	1.4	0.05	0.10	3.55	9.7	37
76-98	3.1	1.4	0.07	0.11	4.68	10.7	44
98-125	4.8	1.5	0.09	0.12	6.51	11.9	55
125-152	4.3	1.5	0.07	0.13	6.00	10.7	56

The Tolanur series consists of moderately deep soils on nearly level low land. Tolanur soils have sandy clay loam surface soil and subsoil layers. They are moderately well-drained. They are formed in alluvium. The slope of the land ranges from 0 to 1 per cent.

The typical pedon of Tolanur sandy clay loam is located on nearly level low land in Kuthannur panchayat, Alathur taluk, Palakkad district.

Ap	0-11 cm	Dark yellowish brown (10 YR 4/4 M) sandy clay loam, moderate medium subangular blocky structure; hard, friable, sticky and plastic; common very fine and fine roots; many fine pores; very strongly acid (pH 5.0); clear smooth boundary.
Bw1	11-36cm	Dark yellowish brown (10 YR 3/4 M) sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; few very fine and fine roots; many fine pores; moderately acid (pH 5.9); clear smooth boundary.
Bw2	36-68 cm	Dark yellowish brown (10 YR 3/4 M) sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; few very fine and fine roots; many fine pores; slightly acid (pH 6.5); clear smooth boundary.
Bw3	68-98 cm	Dark yellowish brown (10 YR 4/6 M) sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; few very fine and fine roots; many fine pores; neutral (pH 6.8); clear smooth boundary.
Bw4	98-121 cm	Dark yellowish brown (10 YR 4/4 M) sandy clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; very fine and fine roots; many fine pores; neutral (pH 7.0).
	121 cm	Water.

Classification: Fine-loamy, mixed, isohyperthermic, Udic Haplustept

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-11	Ap	48.4	19.7	31.9	0	scl	5.0	1.37
11-36	Bw1	49.0	18.9	32.1	0	scl	5.9	0.62
36-68	Bw2	63.3	13.8	22.9	0	scl	6.5	0.19
68-98	Bw3	62.4	12.9	24.7	0	scl	6.8	0.19
98-121	Bw4	64.2	11.3	24.5	0	scl	7.0	0.20

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-11	4.0	2.0	0.15	0.09	6.24	9.5	66
11-36	5.6	3.3	0.11	0.05	9.06	10.9	83
36-68	4.0	2.5	0.09	0.04	6.63	7.6	87
68-98	4.2	2.6	0.08	0.06	6.94	7.3	95
98-121	4.0	2.6	0.08	0.07	6.75	6.8	99

APPENDIX X

Major soils of agro-ecological unit IX

The extensive soils of agro-ecological unit IX belong to Sree Krishnapuram series in the uplands and Kinasseri series in low lands.

The Sree Krishnapuram series consists of deep soils on mid-uplands. Sree Krishnapuram soils have clay loam surface soil and gravelly clay and clay subsoil layers. They are well-drained and rapidly permeable. They are formed on laterite. The slope of the land ranges from 3 to 5 per cent.

The typical pedon of Sree Krishnapuram clay loam is located on uplands of Sree Krishnapuram village of Sree Krishnapuram panchayat, Ottapalam taluk, Palakkad district.

A	0-14 cm	Yellowish red (5YR 5/6) clay loam; moderate medium subangular blocky structure; friable, sticky and plastic; fine and very few medium roots; few medium pores; very strongly acid (pH 4.9); clear smooth boundary.
Bt1	14-33 cm	Yellowish red (5YR 5/6) clay; moderate medium subangular blocky structure; friable, sticky and plastic; few very fine roots; few medium pores; very strongly acid (pH 4.7); clear smooth boundary.
Bt2	33-53 cm	Yellowish red (5YR 5/8) clay; 10 per cent fine gravel; moderate medium subangular blocky structure; friable, sticky and plastic; few medium roots; few medium pores; very strongly acid (pH 4.6); clear smooth boundary.
Bt3	53-76 cm	Yellowish red (5YR 4/6) gravelly clay; 15 per cent fine gravel; weak medium subangular blocky structure; friable, sticky and plastic; few medium roots; few fine pores; very strongly acid (pH 4.6); gradual smooth boundary.
Bt4	76-110 cm	Reddish brown (5YR 4/4) clay; weak medium subangular blocky structure; friable, very sticky and very plastic; very strongly acid (pH 4.6).

Classification: Fine, mixed, isohyperthermic, Typic Kandiustult

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-14	A	38.5	26.7	34.8	-	cl	4.9	2.13
14-33	B1	42.5	16.6	40.9	-	c	4.7	0.51
33-53	B2	33.2	12.0	54.8	10	c	4.6	0.47
53-76	B3	31.9	15.0	53.1	15	c	4.6	0.04
76-110	BC	31.7	19.4	48.9	0	c	4.6	0.04

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-14	2.4	1.0	0.10	0.11	3.6	6.8	53
14-33	0.6	0.8	0.10	0.17	1.7	4.9	35
33-53	0.4	0.6	0.09	0.19	1.3	5.8	22
53-76	1.6	1.0	0.12	0.05	2.8	6.2	45
76-110	1.0	1.0	0.09	0.06	2.2	6.5	34

Kinasseri series consists of deep soils on low lands. Kinasseri soils have gravelly sandy clay surface soil and gravelly sandy clay loam and clay subsoil layers. They are moderately well-drained and permeable. They are formed in colluvium. The slope of the land ranges from 3 to 5 per cent.

The typical pedon of Kinasseri sandy clay is located on low land in Sree Krishnapuram village of Pookottukavu panchayat, Ottapalam taluk, Palakkad district.

Ap	0-18 cm	Reddish brown (5YR 4/4) gravelly sandy clay; 25 per cent fine gravel; moderate medium subangular blocky structure; sticky and plastic; few fine roots; few fine pores; extremely acid (pH 4.4); clear smooth boundary.
B1	18-32 cm	Yellowish red (5YR 5/6) gravelly sandy clay loam; 20 per cent fine gravel; moderate medium subangular blocky structure; sticky and slightly plastic; many fine roots; common coarse pores; very strongly acid (pH 4.8); clear smooth boundary.
B21	32-56 cm	Strong brown (5YR 4/8) gravelly sandy clay loam; 25 per cent gravel; weak medium granular structure; slightly sticky and slightly plastic; many coarse roots; few fine pores; very strongly acid (pH 4.9); clear smooth boundary.
B22	56-83 cm	Strong brown (5YR 4/8) sandy clay loam; weak granular structure; sticky and plastic; few fine pores; very strongly acid (pH 4.9); wavy boundary.
B23	83-105 cm	Strong brown (5YR 4/8) clay; moderate medium subangular blocky structure; slightly sticky and slightly plastic; few fine roots; very strongly acid (pH 5.1).

Classification: Fine-loamy, mixed, isohyperthermic, Oxic Haplustept

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-18	Ap	52.4	2.2	45.4	25	sc	4.4	0.93
18-32	B1	64.9	2.2	32.9	20	scl	5.8	0.54
32-56	B21	56.7	10.2	33.1	25	scl	5.9	0.50
56-83	B22	53.7	13.3	33.0	-	scl	5.9	0.41
83-105	B23	38.2	16.2	45.6	-	c	5.1	0.31

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-18	1.3	0.6	0.01	0.16	2.1	7.0	30
18-32	2.6	1.5	0.02	0.26	4.4	7.9	56
32-56	2.4	1.1	0.02	0.25	3.8	5.7	67
56-83	2.2	1.1	0.01	0.07	3.4	4.9	69
83-105	2.0	0.9	-	0.18	3.1	7.5	41

APPENDIX XI

Major soils of agro-ecological unit X

Soils of two series are most extensive in agro-ecological unit X, Pallippadi in the uplands and Thanikkunnu in the low lands.

Pallipadi series consist of very deep soils on the uplands. They have gravelly sandy clay loam surface soil and sandy clay and clay subsoil layers. The soils are well-drained and permeable. They are formed from weathered granite-gneiss. The typical pedon of Pallippadi series was located on sloping uplands of Pallipadi village, Mannarkkad taluk, Palakkad district; 10° 55′ N latitude and 76° 31′ E longitude.

Ap	0-12 cm	Dark grayish brown (10YR 4/2); gravelly sandy clay loam; 30 per cent fine gravel; moderate medium subangular blocky structure friable, sticky and plastic; common coarse roots; many fine pores; few fine iron concretions; very strongly acid (pH 4.8); gradual smooth boundary.
Bt1	12-49 cm	Dark brown (10YR 3/3) gravelly sandy clay; 20 per cent fine gravel; moderate medium subangular blocky structure; friable, sticky and plastic; few fine roots; common fine pores; patchy thin clay skins; extremely acid (pH 4.4); clear smooth boundary.
Bt2	49-86 cm	Dark brown (7.5YR 4/4) sandy clay; 10 per cent fine gravel; moderate medium subangular blocky structure; friable, sticky and plastic; many fine pores; patchy thin clay skins; extremely acid (pH 4.4); gradual smooth boundary.
Bt3	86-117 cm	Strong brown (7.5YR 4/6) clay; 10 per cent fine gravel; moderate medium subangular blocky structure; friable, sticky and plastic; many fine pores; patchy thin clay skins; very strongly acid (pH 4.5); gradual smooth boundary.
Bt4	117-152 cm	Dark reddish brown (2.5YR 3/4) and strong brown (7.5YR 5/8) clay; 10 per cent fine gravel; moderate medium subangular blocky structure; friable, sticky and plastic; many fine pores; patchy thin clay skins; very strongly acid (pH 5.0).

Classification: Clayey, kaolinitic, isohyperthermic, Ustic Kandihumult

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-12	Ap	64.0	9.0	27.0	30	gscl	4.8	0.99
12-49	Bt1	50.5	9.8	39.7	20	gsc	4.4	0.95
49-86	Bt2	49.2	9.0	41.8	10	sc	4.4	0.77
86-117	Bt3	39.2	11.6	49.2	10	c	4.5	0.55
117-152	Bt4	40.8	18.7	40.5	10	c	5.0	0.24

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-12	1.80	1.00	0.10	0.20	3.10	4.0	78
12-49	1.00	0.50	0.10	0.20	1.80	6.0	30
49-86	1.00	0.70	0.10	0.20	2.00	6.7	30
86-117	1.40	0.60	0.10	0.20	2.30	6.8	34
117-152	2.10	1.50	0.10	0.20	3.90	6.4	61

Thanikunnu series consists of very deep, dark yellowish brown, sandy clay soils in alleys. They are moderately well-drained and moderately permeable. The typical pedon of Thanikunnu series was located in low lands of Sree Krishnapuram village, Pookottukavu panchayat, Ottapalam taluk, Palakkad district.

Ap	0-17 cm	Dark yellowish brown (10YR 4/6) sandy clay loam; weak medium subangular blocky structure; hard, slightly sticky and slightly plastic; weak medium very few fine roots; many fine pores; extremely acid (pH 4.5); clear smooth boundary.
Bw1	17-33 cm	Yellowish brown (10YR 5/4) sandy clay loam; moderate medium subangular blocky structure; hard, sticky and plastic; few medium roots; many fine pores; moderately acid (pH 5.8); clear smooth boundary.
Bw2	33-62 cm	Yellowish brown (10YR 5/4) sandy clay loam; moderate medium subangular blocky structure; very hard, very sticky and very plastic; common fine roots; few fine pores; slightly acid (pH 6.3); gradual smooth boundary.
Bw3	62-97 cm	Yellowish brown (10YR 5/8) sandy clay loam; moderate medium subangular blocky structure; very hard, very sticky and very plastic; few fine roots; common fine pores; slightly acid (pH 6.4); gradual smooth boundary.
Bw4	97-129 cm	Yellowish brown (10YR 5/8) sandy clay loam; weak medium subangular blocky structure; very hard, very sticky and very plastic; very few roots; common fine pores.

Classification: Fine-loamy, mixed, isohyperthermic, Typic Haplustept

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-17	Ap	62.4	17.0	20.6	0	scl	4.5	1.90
17-33	Bw1	52.5	23.2	24.3	0	scl	5.8	0.81
33-62	Bw2	52.2	22.5	25.3	0	scl	6.3	0.36
62-97	Bw3	62.0	15.8	22.2	0	scl	6.4	0.27

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-17	1.4	0.7	0.17	0.22	2.5	4.7	53
17-33	1.6	0.9	0.09	0.06	2.7	4.1	66
33-62	1.7	1.0	0.10	0.06	2.9	3.6	81
62-97	2.1	1.2	0.12	0.10	3.5	4.8	73

APPENDIX XII

Major soils of agro-ecological unit XI & XII

The southern hill region has dominantly deep, well drained soils. A typical pedon of the area is described below.

A	0-12 cm	Dark reddish brown (5YR 3/2 M) sandy clay loam; moderate medium subangular blocky structure; friable, sticky and slightly plastic; many medium and coarse roots neutral (pH 6.7); clear smooth boundary.
Bt1	12-30 cm	Dark reddish brown (5 YR 3/4 M) sandy clay loam; moderate medium subangular blocky structure; firm friable, sticky and slightly plastic; common medium and coarse roots; slightly acid (pH 6.2); clear smooth boundary.
Bt2	30-56 cm	Dark reddish brown (5YR 3/4 M) clay loam; moderate medium subangular blocky structure; friable, very sticky and very plastic; thin patchy clay cutans; few fine and medium roots; few fine pores; neutral (pH 6.7); gradual smooth boundary.
Bt3	56-100 cm	Reddish brown (5YR 4/4 M) gravelly clay; 15 per cent fine and coarse gravel; moderate coarse subangular blocky structure; friable, sticky and slightly plastic; thin patchy clay skins; slightly acid (pH 6.2); gradual smooth boundary.
Bt4	100-156 cm	Dark red (2.5YR 3/6 M) gravelly clay; moderate coarse subangular blocky structure; friable, sticky and slightly plastic; 40 per cent fine and coarse gravel; thin patchy cutans; few coarse roots; slightly acid (pH 6.2); clear smooth boundary.
BC	156-200 cm	Dark red (2.5YR 3/6 M) gravelly clay; moderate, coarse subangular blocky structure; friable, sticky and slightly plastic; 40 per cent coarse gravel; few coarse roots.

Classification: Clayey, mixed, isohyperthermic, Ustic Palehumult

Depth cm	Horizon	Particle-size (USDA) distribution			Coarse fragments vol. %, whole soil	Texture class (USDA)	pH 1:2.5 water	Organic carbon %
		Sand	Silt	Clay				
		% of < 2 mm						
0-12	A	53.1	19.5	26.6	-	scl	6.7	1.85
12-30	Bt1	50.6	18.3	31.1	-	scl	6.2	1.05
30-56	Bt2	38.9	21.6	39.5	-	cl	6.3	0.41
56-100	Bt3	43.0	15.5	41.5	15	gc	6.2	0.30
100-156	Bt4	43.1	15.5	41.4	40	gc	6.2	0.21

Depth cm	Exchangeable bases					CEC (NH_4OAc)	Base Satn. %
	Ca	Mg	Na	K	Total		
	cmol (+) kg^{-1} soil						
0-12	7.04	2.29	0.06	0.63	10.02	12.7	79
12-30	4.67	2.10	0.06	0.47	7.30	9.5	77
30-56	2.94	1.73	0.04	0.43	5.14	7.3	70
56-100	2.93	1.86	0.05	0.43	5.27	8.2	64
100-156	2.43	1.62	0.04	0.30	4.39	7.5	58