A COMPARATIVE MICROMORPHOLOGICAL AND PHYSICO-CHEMICAL STUDY OF THE UPLAND AND MIDUPLAND LATERITE SOILS OF KERALA

BY

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "A Comparative Micromorphological and Physico-Chemical Study of the Upland and midupland Laterite Soils of Kerala" is a bonafied record of research work done by me during the course of research and this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title; or any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "A Comparative Micromorphological and Physico-Chemical Study of the Upland and Midupland Laterite Soils of Kerala" is a bonafied record of research work done independently by Sri. R. Sankarankutty Nair, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

A study of the micromorphology of soils in combination with other mineralo-chemical and physical properties with an appreciation of the geomorphology of the area, provide some insight into the historical development of soils. Thin sections are considered to be most valuable in micromorphological interpretation of the genesis of soils as "soil formation leaves its imprints on the soil" (Easwaran, 1979).

The use of thin sections and microscopic examination and interpretation of soils has developed in recent years especially in Western Europe, U.S.A., and U.S.S.R., as a valuable tool in determining the process of soil formation and classifying soils. The thin section microscopic studies which have been confined mainly to a few advanced countries mentioned earlier mainly with a major stress on micromorphological description with little emphasis on interpretation is, however, getting more refined in recent years with the establishment of an International Group in Micromorphology.

The technique of soil micromorphology introduced by Kubiena in (1938) and formalised by Brewer (1964) has served to create a new breed of pedologists whose basic interest is the microscopic investigation of soils, without too much emphasis on application of the technique to pedological problems. Attempts to study the technique by pedologists however, is more with the intent of making it a more useful tool for confining mácro and micro pedological process otherwise investigated.

Attempts have been made by pedologists to study laterite soil associations in relation to topography (Durairaj 1964, Gowaikar 1972, Gaikwad et al 1974) Subramonia Iyer 1979, Venugopal 1981). Koshy (1962) had recognised three distinct land forms in the state of Kerala viz. Highland, Midland and Lowland. Earlier genetic studies of Kerala laterites were conducted by Satyanarayana and Thomas (1962), Koshy (1962), Gopalaswamy (1969), Gowaikar and Datta (1971), Gowaikar (1972), Subramonia Iyer (1979), and Thomas Varghese (1981). Schmidt-Lorenz (1977), Gopalaswamy (1969) were the pioneers in the micromorphological studies of Kerala laterite soils. According to Schmidt-Lorenz (1979) acid igneous granites undergo primary fertilisation with the export of SiO_2 and bases leading to yellow saprolite (a mixture of kaolinite, ferric hydrite and quartz), upper horizon undergo pedoplasmation and lower horizon undergo plinthitisation resulting in a yellow solum and violet saprolite. Subsequently a mixing of material takes place as a result of erosion and colluviation leading to reddish-red solum with transported products of plinthitisation. He considered the formation of a reddish red solum as "plinthorhodofication distinct from "rubification" which is a process of in situ transportation of yellow coloured amorphous material.

Gopalaswamy and Nair (1972) reported that laterite samples collected from the same site revealed diversity in structure and composition in thin sections. Subramonia Iyer and Gopalaswamy (1982) reported that laterite soil of a foot slope in Trivandrum district studied is pre-weathered prior to deposition. Runicquartz, rounded lateritic micro aggregates is observed in the profile sample thin sections. It is also observed that clay illuviation is just commencing. Subramonia Iyer <u>et al</u> (1983) in their study on micromorphological comparison of three rice growing laterite soils of different physiographic positions found that soils are in the increasing order of weathering; wet land Palliyal Upland (modan) due to comparative difference in the exposure to precipitation and insolation.

Thus though micromorphological techniques have been used and laterite soils studied for the last several years, the technique has not been applied as yet to detailed studies on laterites.

The scope for such a study exists in Kerala where laterisation is the over riding soil forming process in almost all the locations. The differences however, are mostly due to the nature of the material undergoing laterisation ie. residual or detrital. Further the extent and stage of laterisation as well as the similarities and the dissimilarities of the process in various topographical situations have not been fully examined. Soil thin sections or micromorphological methods become the best tool for such investigation.

In view of this a study on the effect of vegetation, topography and climate on the extent of laterisation in three locations on identified slopes enabling micro studies at each location was initiated. The major objectives of the work are as follows:-

1) To study the Micromorphological differences between the soils of different physiographic positions and endeavours to correlate field properties with microscopical observation.

2) Study of the physical-chemical and mineralogical differences among these soils.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The word "laterite" was first coined by Francis.H. Buchanan (1807) to denote ferruginous material occuring in masses over the country rocks of Malabar.

Harrassowitz (1930) tried to define the laterite soil for the first time based on morphological features.

Robinson (1949) used pedological definition ie., ferralization and resultant pedon was termed as ferrallitic soils. Kellogg (1949) suggested the term latosol to denote lateritic soils and ferruginous material which hardens on exposure.

Regarding the genesis of the laterite soil a number of work has been done by Voysey (1833), Oldham (1893), Glinka (1927), Harrison (1933), Prescott and Pendleton (1952), Sathyanarayana and Thomas (1961), Alexander and Candy (1962), Sivaraja Singham et al (1962), Maignien (1966), Mandal (1971) Raychaudhuri and his associates (1971) Govindarajan et al (1972), Gowaikar (1972), and Schellmann (1979).

Genesis

Laterisation is favoured by fine textured basic rocks derived under humid tropical climate with high temperature and rainfall with intermittant dry period. Due to this organic matter gets decomposed rapidly leaving basic ash residue, which percolated down on receipt of rain causing alkaline hydrolysis and thus silica is leached down the profile leading to accumulation of sesquioxide in the surface of the soil (Patnaik, 1971). Though high rainfall is favourable for laterisation, excess rainfall with high intensity do not enhance laterisation (Gowaikar and Dutta, 1971).

Satyanarayana and Thomas (1961) studied certain profiles of laterite and associated soils at three locations in Kerala and another one at South Canara district of Mysore. They found both gneissic and basaltic rocks beneath laterite. Hamilton (1964) pointed out that low level laterites are formed by ferruginisation of colluvial deposits. The iron colloids from upland may flow to these low level deposits.

Effect of climate

The relation between temperature, rainfall and genesis of the soil has been studied by Maignein (1966). He observed the laterisation process of various isolates and is of the view that these soils are mostly seen in tropical environment where annual precipitation is at least 1200 mm.

Buringh (1970) has reported that when the soil temperature is 24 to 27°C throughout the year with a mean precipitation of 3000-6000 mm/year ferralitic soils formation is favoured.

Gowaikar and Dutta (1971) has studied the influence of moisture regime on the genesis of laterite soils of

South India. They have observed that a high rain-fall of about 2300 mm distributed over a period of 9 months retarded laterisation as compared to the area receiving same rainfall distributed over seven months.

de-Chatelat (1938) observed that laterite develops under high precipitation in forest vegetation.

Topography

Maignien (1966) suggested that laterites principaly occur on flat surfaces or on gentle slopes. Buringh (1970) has expressed the opinion that laterite soils have been developed in places with undulating and rolling terrain with good natural drainage. Roy and Paul (1974) have studied the West Bengal laterites and have pointed out that the prominance of topography in the laterite formation.

Morphological and analytical characteristics

Dhoor'e (1954), Sys (1960), Alexander and Cady (1962), Prescott and Pendelton (1952) in Australia and Bennema (1963) in Brazil have conducted detailed investigations on laterite soils. But they have not arrived at a generalisation with regard to characteristics of laterites.

Morphological Characteristics

Colour:

According to Satyanarayana and Thomas (1961) the main physical properties of laterite soil are the colour, consistancy and structure. Menon and Mariakulandai (1957) reported that the colour of the soil is mainly due to ironoxide which occur as coating, on the soil particle. Whenever haematites or unhydrous ferric oxide is predominant, red colour is imparted, while yellow colour is due to limonite or hydrous ironoxide. If both forms are present a mixture of both colours are imparted. Durairaj (1961) has correlated the colour with various properties of the soil. He observed that the reciprocal of Chroma of soil colour is highly correlated with clay content. Satyanarayana and Thomas (1961) observed that the colour of the laterite soil is imparted by oxides and hydroxides of iron. According to Purushothaman (1964) the dark colour of soil is closely correlated to organic carbon content.

Gopalaswamy (1969) has observed that in the Varkala beds there is not much difference in colour in different horizons, while at mid-upland region of Chingavanam showed variation within and between profiles.

Buringh (1970) has classified latosols based on colour as red latosols, dark red latosols, yellow latosols, brown latosols, etc.

Govindarajan and Gopala Rao (1978) reported that the colour of laterite soil at the surface in most case is red changing to reddish yellow and finally yellow in deeper layers.

Curi and Franzmeir (1984) observed that in a toposequence of oxisols developed from basalt in central plataue of Brazil the moist colour of dark yellow (2.5 YR 3/4) in upper slope changed to yellowish brown in lower strata (10 YR 4/4).

Texture

Mohr, and Van Baren (1954) while summarising the findings of early scientists have come to the conclusion that the textural homogenety characterises the laterite soils of different regions in all over tropics.

Gopalaswamy (1969) observed a decrease in sand fraction with depth in the case of laterite soils. Similar results have been recorded by Gowaikar and Dutta (1971).

Thomas Varghese (1981) found that the coastal and mid upland contained more gravel than the forest upland. More fine sand fraction is found in the coastal region. The coarse fraction is also found to decrease with depth.

Kellogg (1949) observed that the intensively weathered laterite soils contain less of silt fraction. Bennema (1963) has also reported a low content of silt in intensively weathered laterite soils.

Buringh (1970) has proposed a high value silt/clay ratio of 0.25 for ferralitic soils.

Gopalaswamy (1969) observed clay films in West coast laterites in B. horizon.

Gowaikar and Dutta (1971) observed that in South Indian laterites clay content increased in subsurface with continuous clay films in the same pedon while it is absent in some others.

Thomas Varghese (1981) reported that the high land contained more amount of clay in surface layers. In coastal area B horizon contained more clay.

Structure

Biswas, et al (1961) studied the aggregate composition of surface and subsurface soils of few Indian soils by wet sieving in Yoder's apparatus. He observed that aggregate size group differed among soils. In red, alkali and colluvial soils aggregates less than 0.1 mm is maximum. Except in colluvial soils the surface layers contained large sized aggregates of 0.25 mm and above as compared to subsurface layers. He also observed that ferricoxide is correlated to aggregation except in black and alkali soils.

Tabatabai and Hanway (1968) studied the physical and chemical properties of the aggregates and found that an increase in organic carbon decreased the size of aggregates.

Satyanarayana and Thomas (1961) observed that in Malabar and South Canara region where laterite occur below a soil cover, top portion of laterite is brittle and they shatter when cut and crumble to irregular masses. According to them the structure changes to vermicular with depth.

Bulk density, Particle density and water holding capacity

Subbarao (1960) found that there is positive correlation between clay and pore space, volume expansion and water holding capacity.

Manickam (1965) has reported that pH do not have to do much with bulk density, porespace, volume expansion and waterholding capacity.

Gopalaswamy (1969) has reported that bulk density of forest soil is less while that of coastal area is more. He has also observed that bulk density increased with depth. Subramonia Iyer (1979) observed that the porosity and water holding capacity increased with depth which is due to the influence of clay fraction and the sand fraction has got a negative correlation. Thomas Varghese (1981) found that the bulk density of high land soil is low at surface layers. The low volume expansion indicates the presence of non-expanding type of colloidal material.

Chemical properties

Satyanarayana and Thomas (1962) have made a critical account of chemical properties of west coast laterites. They observed that soil is highly acidic and the profiles are low in bases. The top soil and intermediate layers are rich in iron content.

Gopalaswamy and Nair (1972) while working with laterite soils of Kerala observed that the soil is acidic in reaction. They have also observed that the pH decreased with depth. They have postulated that this is due to advanced stage of decomposition with depth.

Cation Exchange capacity

Satyanarayana and Thomas (1962) observed that the laterite soils have a low C.E.C. Menon and Mariakulandai (1957) have reported that the red soils have got low C.E.C. due to high content of Kaolinite.

Durairaj (1961) while working with laterite soils of Tamil Nadu observed that the C.E.C. is correlated to the clay content.

Lavati, et al (1969) found that the clay, silt and organic matter of the soil are significantly correlated to C.E.C.

Mandal and Das, (1970) have reported that the laterite soils are poor in organic carbon and nitrogen. Similar observations have been recorded by Koshy and Thomas (1972) and Ratnam, et al (1972).

Rajamannar, et al (1975) while working with soil samples at different elevations observed that the organic carbon content was more at high elevation with high rainfall and low temperature.

Subramonia Iyer (1979) has observed that organic carbon content decreases with depth. Further a positive correlation is observed between organic carbon and nitrogen in the laterite soil.

Sahu, et al (1983) observed the organic matter content decreased with depth in laterite soils of Orissa.

Iron

Pisharody (1968) studied the forms and distribution of the iron in six soil profiles of Kerala. He has observed that the soil is adequately supplied with available iron.

Balaguru and Dhanapalan Mosi (1972) while working with soils of Tamil Nadu have found that in alluvial soils iron content decreases with depth.

Choudhuri, et al (1979) have observed that in the Rajastan soils free iron content is more in the subsurface which may be due to high content of clay and advanced stage of weathering due to high rain fall and temperature.

Thomas Varghese (1981) reported that in high land under forest vegetation there is no increase in iron content with depth.

Phosphorus and potassium

Koshy and Thomas (1972) have reported that the laterite soils of India in general are poor in available P. It has got a high P fixing capacity due to the presence of high amount of sesquioxide.

Subramonia Iyer (1979) has reported that the laterite soils in general has a low content of available P and K. The P content is found to decrease with depth.

Thomas Varghese (1981) has reported that phosphorus content is more in upper horizons. Further the P content of coastal laterite is less than that of high land. The same author has also found that high level laterite of forest region has got more amount of potassium than the low level laterites.

Calcium and Magnesium

John (1958) found that the major portion of exchangeable ion is contributed by calcium followed by magnesium and potassium in the red soils of Venezula.

Durairaj (1961) while working with laterite soils of Tamil Nadu has found that calcium is the predominant exchangeable ion.

Venugopal and Koshy (1976) found that total calcium content of Kerala soils ranged from 0.2 to 2.03 percent.

Thomas Varghese (1981) while studying the laterite soils of different locations of Kerala has observed that the calcium and magnesium is low in coastal and mid uplands. But upper horizons of the upland contained more amount of calcium and magnesium.

Durairaj and Mahalingam (1968) observed that high level soils of Nilgiri area contained low amount of magnesium.

Hassan (1977) in his studies with laterite soils of Kerala has found that magnesium content is very low in these soils. Further magnesium is found to decrease with depth..

Mineralogy

It is an accepted fact that the physical and chemical properties could alone account for the nature and origin of laterites. The fact that the soils having same chemical properties have a different mineralogy lead to think and study more about it. The credit at this venture goes to Joffe (1949), Sivarajasingham, et al (1962) and Mc-Farlane (1976). Their work has revealed the presence of Kaolinite, gibbsite, halloysite, bohemite, haematite, goethite and residual iron-oxides like magnetite, limonite together with zircon, anatase, quartz etc.

Agarwal, et al (1957) worked with catenary soils of upper Vindhyan plataue and observed that distribution of light minerals are uniform in all horizons. The common light minerals observed are quartz, feldspar and mica. But the grains showed variation in size, shape and degree of weathering.

Gawande _et al_ (1963) while working with catenary soils of Madhyapradesh observed that quartz and orthoclase feldspar form the major portion of the primary minerals. Other minerals observed is Zircon, tourmaline, magnetite, mica, hornblende, sillimanite, apatite, etc.

Maignin (1966) observed that the main factor determining the mineralogy is the drainage and ionic concentration of percolating water. High rainfall favours crystallisation of aluminium hydroxide in gibbsite.

Singh and Gangawar (1971) while studying the mineralogy of rock and fine sand of Vindhyan soils of mirzapur observed that quartz is the major fraction of the fine sand portion of the soil.

Gowaikar (1972) observed that the laterite soils under all moisture regimes in the central regions of Western hills sloping West ward in Kerala and Mysore are dominant in kaolinite and small quantities of quartz in clay fraction. Further gibbsite occurs in high excessive rain fall area, but is absent in low rainfall area.

Sankar and Raj (1973) while studying the mineralogy of sand fraction of South Indian soils observed that the minerals present are in conformity with the parent material rock. The laterite soil is found to be rich in iron bearing minerals. Limonite is found to be dominant in low level laterites. Zircon is present in all soil groups.

Gakewad, et al (1974) observed that in catenary soils developed over basalt, light mineral portion is constituted by fieldspar (is stained and angular). Quartz is angular and subangular without inclusions. Haematite, magnetite, illmenite, epidote, chlorite, hornblende and Zircon formed the heavy mineral fraction.

Lespsch and Boul (1974) while working in oxisol - ultisol toposequence showed that quartz is the dominant mineral in sand fraction. Opaque grains are the second which decreased from top to bottom.

Saratchandran Nair (1977) observed that in Wynadu rice soils quartz is the dominant mineral in all profiles except in one sample where opaque minerals are dominant.

Murali, et al (1978) while working with rock and soil samples of the topsequence in South India, observed that quartz is the dominant light mineral fraction followed by feldspar. Heavy mineral fraction is constituted by magnetite and biotite.

Chakravarthy, et al (1979) studied the distribution, size and shape of minerals in eight pedons developed under different climate and topography in Southern bank of Brahmaputra river. Major portion of fine sand is constituted by light mineral quartz with little amount of feldspars and mica. Some grains are fragmented while others are coated with ironoxide or clay. Heavy mineral fraction is constituted by Zircon, Chlorite, biotite, amphibole, garnet, etc. Soils developed on upland showed weatherable minerals like feldspars, mica, etc. which increased with depth and quartz decreased with depth.

Subramonia Iyer (1979) working with the fine sand fraction of laterite and red soils association of Kerala, observed that quartz is the dominant light mineral fraction. Mica is present in traces. Zircon is also observed.

Venugopal and Koshy (1982) observed that quartz is the dominant light mineral. The quartz is found coated with ironoxide. The heavy mineral fraction is comparatively less and it did not show any regular trend in profile. In the upper slopes more percentage of haematite is observed. The haematite content reduces with decrease in elevation. No variation in zircon is found at different locations.

Thomas Varghese (1981) while working with laterite soils found that the resistant minerals are abundant in coastal and mid land locations while high land contained few weatherable minerals.

Micromorphology

During the early part of thirtees Kubiena introduced microscopic and stereoscopic investigation of undisturbed

Samples of soils. This led to a new era in soil science and a new concept of research was born which is known as micro-morphology. It covers all branches of soil science and enables to understand the changes that is undergoing in the soil which takes place in microscopic dimensions.

Kubiena (1962) followed by Alexander and Candy (1962) have explained formation of iron microaggregates through precipitation of peptised amorphus ferrous hydroxide with a thick brownlehm matrix.

Schmidt - Lorenz (1964) hase investigated the micro-morphology of the laterite soils of Kerala and Ceylon. They described the relative accumulation of ferric oxide sphere aggregates with haematite as final product. This process take place with a colloid rich matrix.

Costangal (1940) observed that brown constituents of laterites are rich in iron, grey earthy constituents are rich in clay, white areas are rich in alumina. Nodular con-cretions are either similar in composition to the enclosing matrix or different in composition especially in certain less combined silica and FeO.

Alexander and Candy (1962) while working with soils of Africa observed that the nodules had a high content of sesquioxide and low silica.

Panegue, and Ballinfante (1964) have studied the micromorphology of the brown forest soil and Mediterranean at different elevations which has got a mountainous relief. They observed that in all horizons the plasma is dense and compact. Sand fractions contained minerals like hornblende which increases with depth. In light mineral fraction quartz is abundant. Kaolinite is present in all layers. Soils developed from granite showed abundant skeleton; mainly of alkaline feldspar, quartz and hornblends. B. horizon has got a birefringent dense plasma which is more or less porphyric.

Rutherford (1964) observed that the matrix in yellow brown soil formed from andesitic ash in high land of New Guinea is composed of mainly magnetite with gibbsite and amorphus material while Cutan is composed of gibbsite and little of magnetite.

Schmidt-Lorenz (1964) observed that relative accumulation of Fe and Al by process involving tiny Feo-sphero-aggregates with haematite as final product occurs in laterites of Kerala. The process takes place within the matrix which is rich in colloids.

Erwinfrei (1964) observed that in latosols, flake like, sharply bordered opaque concretions of ironoxide, resting in a whitish very fine textured matrix are characteristic of oxic horizons. Formation of ferric concretion depends on chemistry of parent material as well as æration and hydrology.

Real cutans are rare in brown latosols of Ecudator. In soils developed on calcareous parent material in warm tropical climate where there is alteration of strong wet and dry spell, only a part of iron is concentrated in concretion. The rest impregnates the clay and hence matrix is reddish brown in colour.

Dhir (1971) has studied the micromorphology of some soils of North Western Himalaya. He observed that at high altitude B_2 horizon has ferrohumic accumulation which are confined to pores and cavities and are alluvial in nature. A_2 horizon has got brown coloured plasma which is an indication of aggressive action of organic acids on microscopic scale. At medium altitude profile shows argillic accumulation in pore cavities. The movement of clay colloid in the face of well coagulated plasma in A_1 horizon is thought to be linked with sudden wet mansoon phase that follows dry summer.

Easwaran and Raghu Mohan (1973) have studied the micromorphology of petroplinthite and observed that laterite is formed from Kaolinite mass by absolute enrichment of Iron-oxyhydrates. Iron forms a vessicular net work. Vaccules are composed of original kaolinite and net work is formed by closely crystallising goethite. Goethite gives the form and hardness of petroplinthite.

Elliott and Sparkes (1981) have observed that iron occurred principally as coatings rather than discrete mineral entities in soil matrix in B horizon.

As far as laterite soils of Kerala is concerned the study conducted by Gopalaswamy (1969) is the only detailed investigation on micromorphological aspect. He had studied the micromorphology of laterites at different locations of Kerala State ie. Cheruvathoor, Kariyamcode, Mannuthy followed by Vellanadu and Varkala. He has observed following features at these localities. At Varkala angular quartz grains are observed in a scattered state, heavily impregnated concretion like bodies are present. There are no concretions that seems to be formed in place but the dense structure of clay balls could indicate the formation of incipient concretions. Crystalline materials like goethite, haematite, gibbsite, quartz and some kaolin are present. Most of the gibbsite had no regular shape or arrangement. Pure aggregates are rare. Gibbsite neo-formations are noticed. It sometimes covers the clay. Ironoxide appears to be in the form of micro aggregates enclosed in gibbsite ground mass. In general extreme heterogeneity of the soil material is noticed at various depths of the profile. Organic matter is dispersed and exhibited features of matric humus. Skeleton particles are densly distributed. At Vellanadu the matrix is seen densely packed and hence few compact concretions with defenite smooth boundaries are noticed. Ironoxide stained kaolin, mica, goethite and haematite are also observed. Medium to fine sized quartz are seen scattered throughout the section. Part of the matrix has got laminated clay. Some of it looked amorphus or fine grained. Heavily impregnated areas and opaque concretions are observed.

Kenneth L White (1981) studied the micromorphology of quartz grains from three soils developed in granitic alluvium by scanning microscopy at California and observed that age in fact have great significance than change in soil texture. The optical properties are largely a function of mineralogy. The plasmic fabric and the related distribution pattern are two parameters which may be used. The different microstructural elements in the field are expressed as kinds of plasmic fabrics and R.D.P.

Easwaran and Banos (1976) have pointed out that the related distribution pattern is a function of the texture of the soil. They have also observed that specific distribution pattern is a function of the texture of the soil. In sandy soils an inter textic and dermatic specific relative disrtibution pattern may arise through clay accumulation. The cutans occur as bridges between sand particles in the former and as complete coatings in the later. In the field such argillic horizons have a friable consistance and it is only with the use of thin sections one can be sure, that the interangular plasma is due to illuviation. In sesquioxidic material the plasma tends to aggregate and a specific kind of specific relative distribution pattern termed agglutanic is formed. This specific relative distribution pattern is common in oxisols and in some ultisols.

The expression of the plasmic fabric is a function of mineralochemical properties of the soil and it changes with evolution of the soil (Easwaran, 1972).

MATERIALS AND METHODS

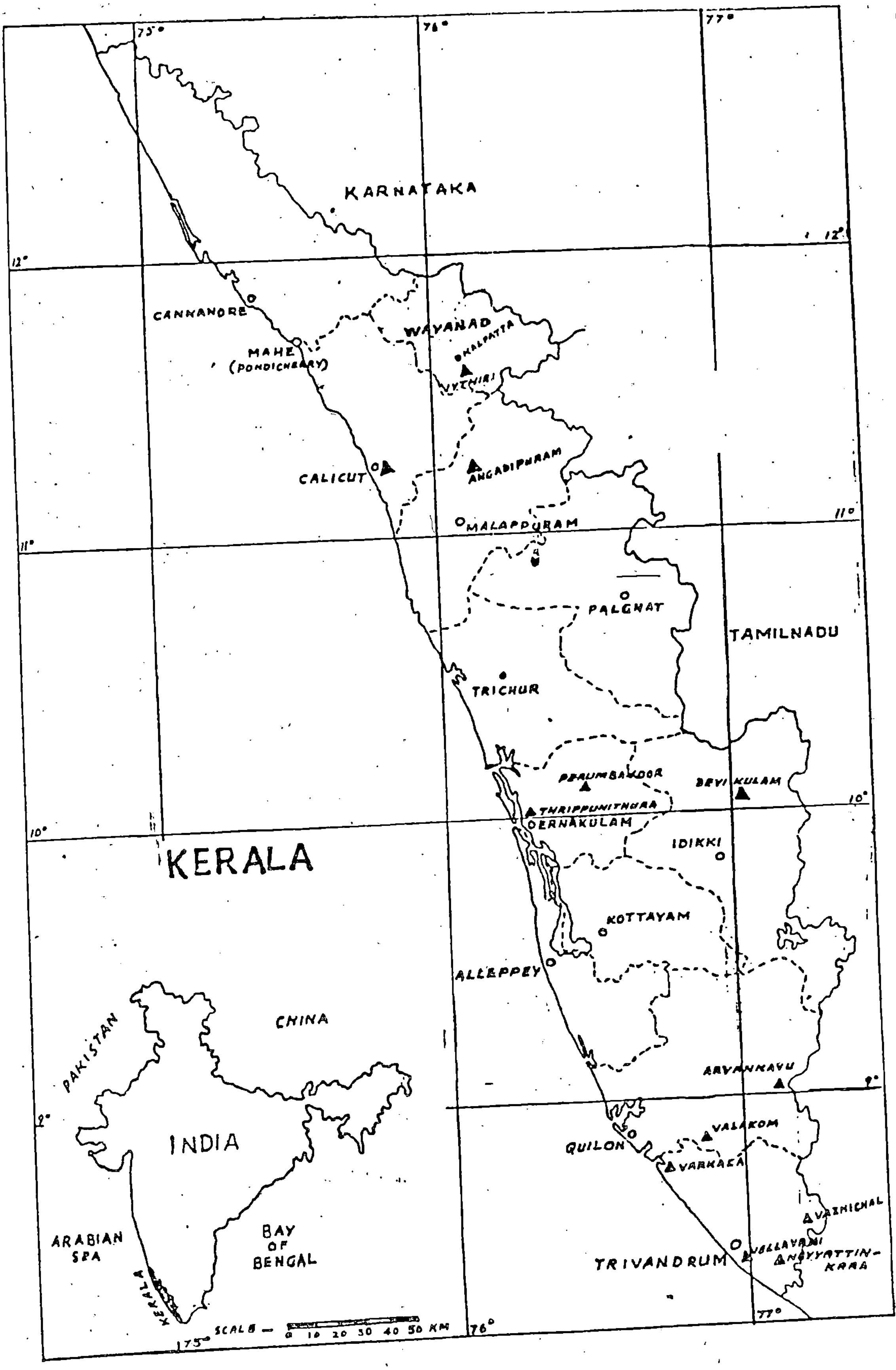
MATERIALS AND METHODS

In order to study the morphology, micromorphology and physico-chemical properties of upland and midupland Laterites of Kerala specific locations were selected. The locations selected represent the forests, mid land region and tertiary beds of Varkala. All the sites located were at different elevation, moisture regimes and having different vegetation.

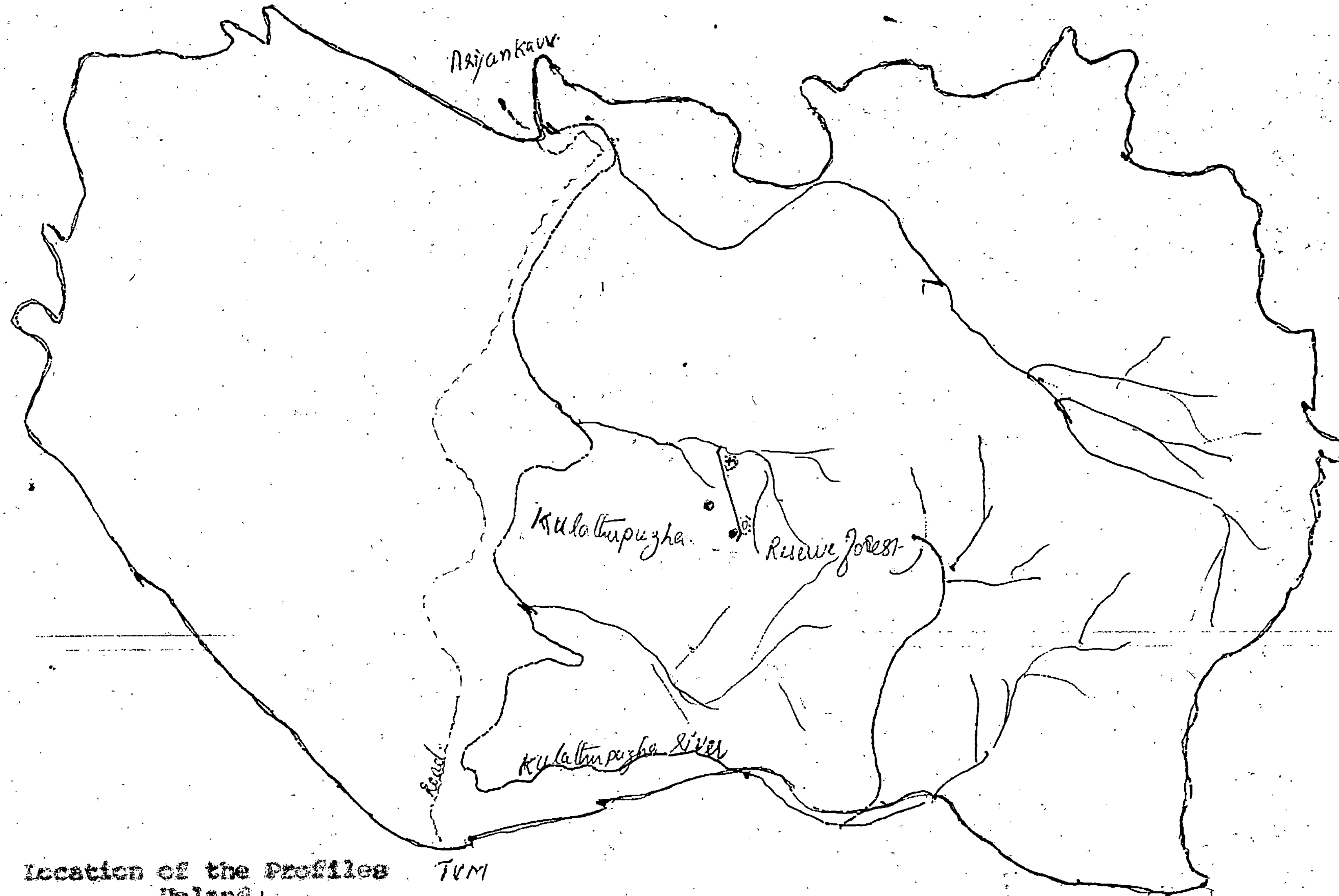
However, while selecting the locations care was taken to see that they are situated in the same latitude. Nedumangad and Varkala receive a moderate rainfall while the Kulathupuzha region receives a higher rainfall distributed throughout the year. Kulathupuzha is a forest region with least disturbance while the Nedumangad and Varkala regions are under considerable human influence being cultivated areas.

Two profiles were dug at each location as per prescribed procedures. While selecting the two sites for each location care was taken to ensure that one of them in midslope with an elevation difference of 50 meters. The profile was dug to a depth of 1.5 m. Since the diagnostic horizon could be obtained with in this depth.

The profile features and insitu observations were recorded as per the F.A.O. guide lines. After demarcating

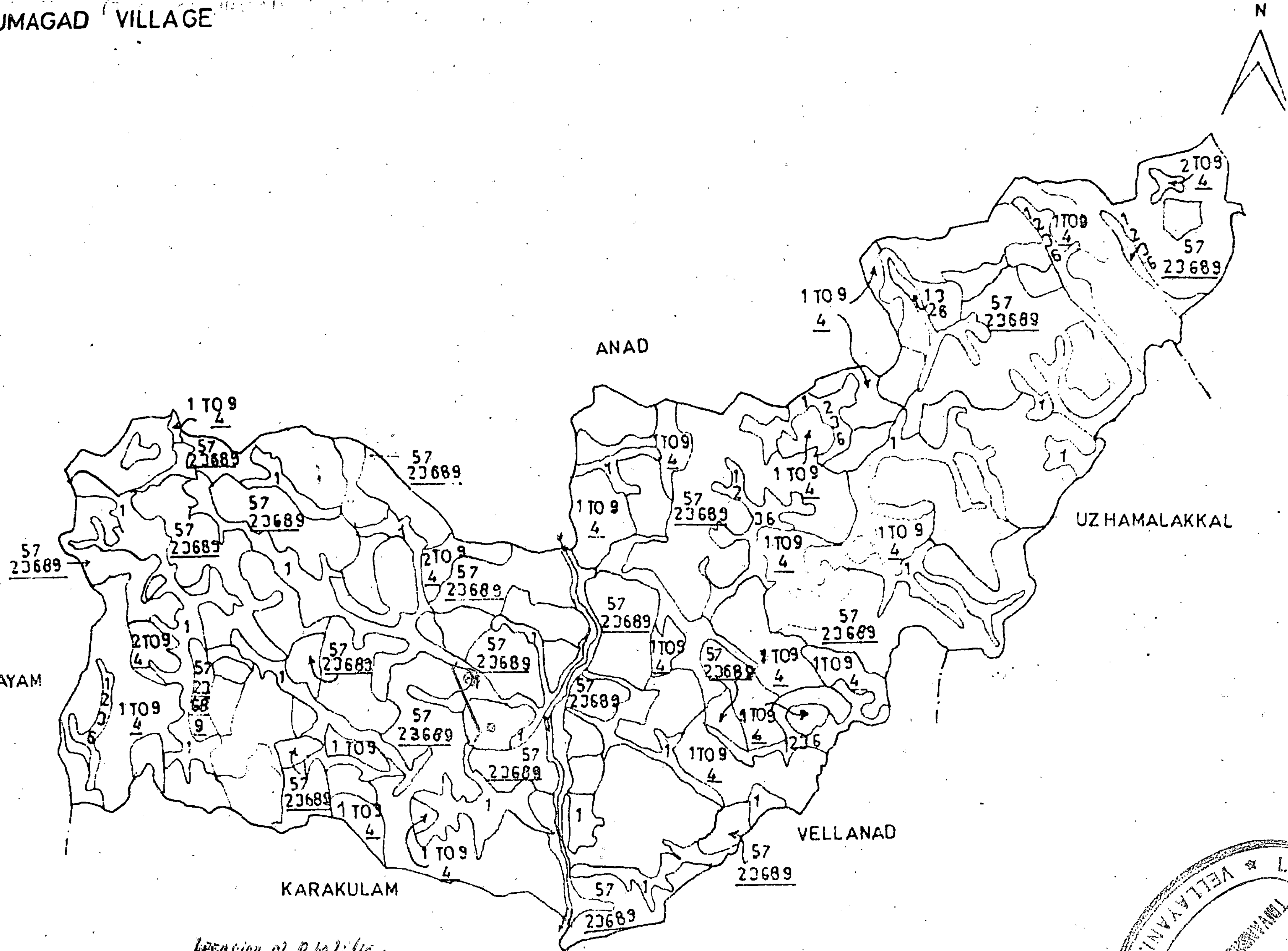

KARNATAKA
CANNANORE
MAHE
(PONDICHERRY)
WAYANAD
CALICUT
ANGADIPURAM
MALAPPURAM
PALGHAT
TAMILNADU
TRICHUR
PERUMBAVOOR
THRIPPUNITHURA
ERNAKULAM
IDIKKI
KERALA
KOTTAYAM
ALLEPPEY
ARYANKAVU
VALAKOM
QUILON
VARKALA
VAZHICHAL
TRIVANDRUM
NEYYATTINKARA
CHINA
PAKISTAN
INDIA
ARABIAN SEA
BAY OF BENGAL
KERALA
SCALE — 0 10 20 30 40 50 KM
75°
76°
77°
12°
11°
10°
9°

KULATUPUZHA VILLAGE

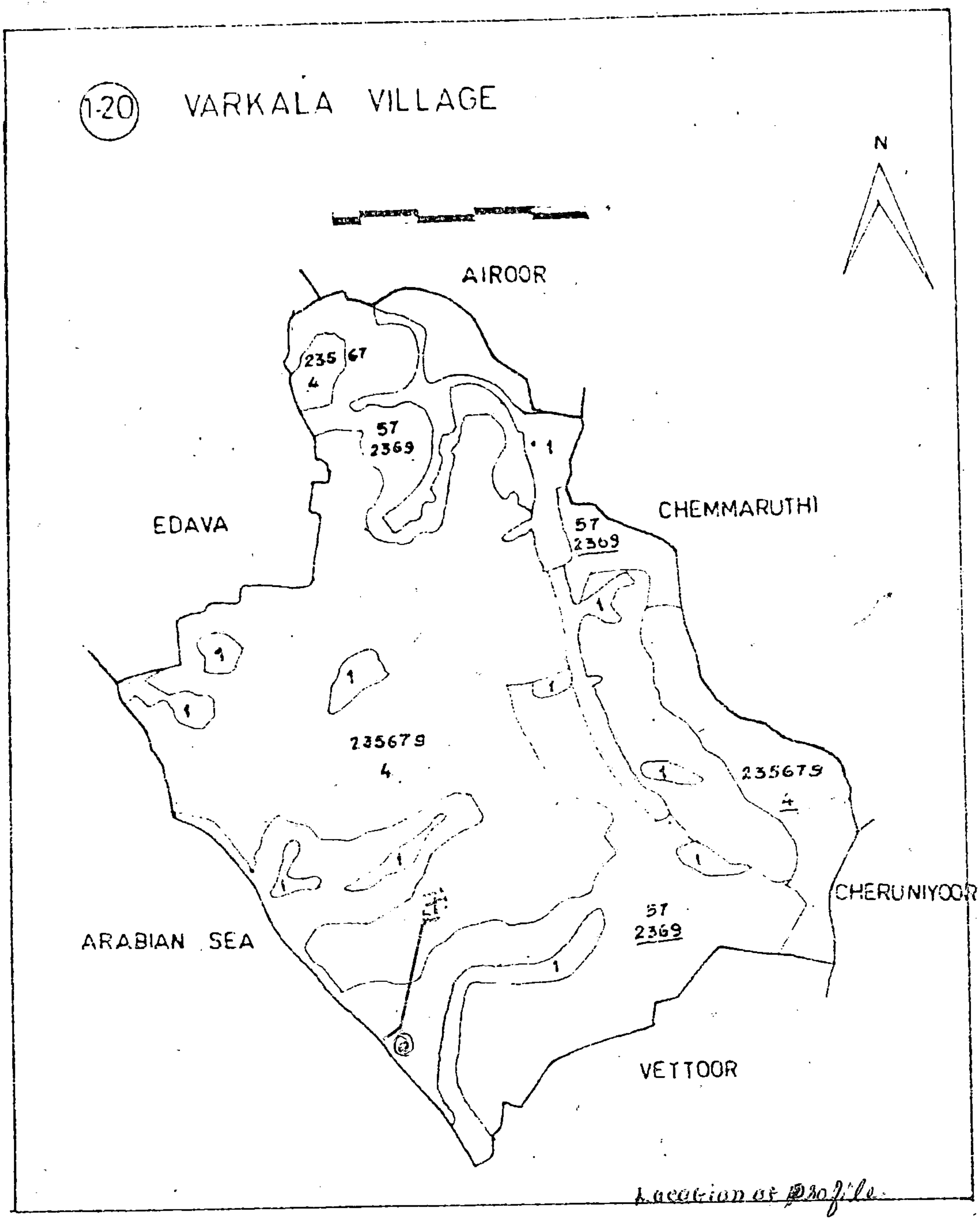


Location of the Profiles
Upland+

(3-11) NEDUMAGAD VILLAGE



Location of profiles.
upland +
Midupland o



Location of profile.
Up land.
Mid up land

each horizon, undisturbed samples were taken using Kubiena box. Then bulk samples were also collected from different horizons for analysis. Core samples were also collected to determine the bulk density and other physical properties. The colour of the soil was recorded using Munsell Soil Colour Charts. The colour was recorded on field moisture condition.

Laboratory Studies

All the bulk samples were air dried in shade and big clods were broken with a wooden mallet. Then the samples were sieved through the 2 mm sieve. The materials were now collected, gravel content was quantified with respect to material passing through 2 mm sieve.

Physical properties

i) Moisture percentage: Air dried samples were used for this purpose. 10 g of soil was taken into a previously weighed china dish and it was placed in an oven kept at 105°C for 24 hours, cooled and weighed. The process was repeated till constant weight was obtained. From the difference in weight moisture percentage was calculated.

ii) Soil colour

The soil colour was determined by using the Munsell Soil Colour Chart.

iii) Mechanical analysis

The mechanical composition of the soil was determined by international pipette method after oxidation of organic matter with hydrogen peroxide. Cementing agents were removed by treating with HCl and sodium hydroxide which enables dispersion (Piper, 1967).

iv) Single value constants

Particle density, waterholding capacity, volume expansion, porespace etc. were determined by using Keen-Raczkowski box method (Wright, 1934).

II. Bulk Density

Bulk density was determined as described by Dakshinamurthi and Gupta (1968).

III. Aggregate analysis

Aggregate analysis was done by wet sieving using Yoder's apparatus as described by Dakshinamurthi and Gupta (1968).

Chemical characteristics

I. Soil reaction

a) The soil pH was determined using 1:2.5 soil water suspension with pH meter.

b) pH was measured with (1:2.5) soil KCl (1N) solution using pH meter.

c) pH was measured with (1:2.5) soil sodium fluoride (1N) solution using pH meter.

II. Electrical conductivity

Specific conductivity was measured in 1:2.5 soil water extract using conductivity bridge.

III. Organic carbon

Organic carbon was determined by Walkley and Black's rapid titration method (Jackson, 1973).

IV. Total nitrogen

The total nitrogen was estimated using the microkjeldhal's method (Jackson, 1973).

V. Available Phosphorus

Phosphorus was estimated by colorimetry. Five grams of soil was extracted with 50 ml Bray No.1 solution. 5 ml of the aliquot was then made upto 50 ml. Added 1 ml stannous chloride and resultant colour developed was read after 10 minutes but before 30 minutes in a Klett-Summerson photo electric colorimeter using red filter (/" 660).

VI. Potassium (Available)

Potassium was estimated using flame photometer (Jackson, 1973). 20 g of soil was treated with 25 ml of neutral normal ammonium acetate and kept over night. Washed with neutral normal ammonium acetate filtered and the volume made upto 150 ml. An aliquot was then aspirated in a EEL flame photometer and the reading recorded.

VII. Calcium

Calcium was estimated using Atomic Absorption Spectrophotometer. 5 ml neutral normal ammonium acetate extract of the soil was made upto 50 ml, fed to the atomic absorption spectrophotometer and the amount of calcium present was determined.

VIII. Magnesium

From the extract prepared for the estimation of potassium 5 ml aliquot was pipetted out and volume made upto 50 ml. The amount of magnesium was read in Atomic Absorption Spectrophotometer.

IX. Total Fe_2O_3

HCl extract was prepared first (Piper 1967). Then the total Fe_2O_3 was determined from the HCl extract after reduction with stannous chloride and titrated against standard potassium dichromate using potassium ferricyanide as indicator (Piper, 1967).

X. Cation exchange capacity

Cation exchange capacity was determined using neutral normal ammonium acetate as described by Jackson (1973).

Mineralogical analysis of fine sand fraction

The fine sand was separated and examined under petrological microscope. Preliminary treatment and separation based on Stoke's law was conducted (Carver, 1971).

Slides of the fine sand separated was prepared (Carver, 1971) for microscopic examination.

A clear slide was placed on a slide warmer and a drop of Canada balsam was placed on the slide. When the bubbles were expelled fine sand grains were sprinkled uniformly over the molten Canada balsam and allowed to settle down. After ensuring enough time for the Canada balsam and slide to get, it was removed from the hot plate, one edge of a cover glass was now placed over the puddled resin and then the cover slip was rotated and pressed gently to push out bubbles and excess canada balsam. After this excess canada balsam solidified on the edges of the cover slipe was scraped off and further cleared with Xylene.

Micromorphological analysis

Thin section of soils for Micromorphological study were made following the procedure described in the soil survey Investigation Report No.1, Soil conservation service, USDA (1967).

Undisturbed soil samples were collected in Kubiena boxes as well as clods of convenient size were also selected.

The orientation of the clods or the samples in the boxes were marked. They were then individually cooked carefully in canada balsam taking care to avoid over heating. The cooking process was continued till bubbles almost ceased to appear indicating the filling of voids by the resin. The sample was taken out carefully and cooled for a while and placed inside an oven maintained at 60°C. After every 2 hours the temperature was raised by 10°C. This was continued till the temperature reached 110°C. The sample was then taken out and kept in a dessicator for 24 hours.

After 24 hours the soil block was taken and one side was ground with carborandum 60, 120, 400 and 600 grade. Then final polishing was done with alloxite 800 and 1000 grade. The polished smooth surface was fixed to a glass slide using Lakeside 70 cement.

The other side of the chip was ground using carborandum 60, 120, 400 and 600 grade power. Final polishing was done with alloxite 800 and 1000 grade till the chip attained a thickness of 20 μ . A cover glass was now fixed on the polished chip, using molten canada balsam avoiding air bubbles. Excess Canada balsam was removed by washing with Xylene. The slide was put under polarised microscope and observations were recorded under ordinary and polarised (crossednichols) light. Photographs were taken and interpretations made.

RESULTS

Macromorphology

The comparative macromorphological description viz., colour, texture, structure, stickness and plasticity, Boundary, presence of roots, permeability, concretions, mottling, Topography, Land use, Drainage, Depth of water table, Erosion, etc. are given in table 1 and 1.1. Description is done as per FAO guideline (1968).

Colour

The colour of the Kulathupuzha upland profile is dark brown in the surface layer and yellowish brown in subsurface layer. A similar observation is recorded for the upland profile at Nedumangad. Varkala upland profile has dark brown soil in the surface horizon changing to reddish brown in the subsurface layers.

The midupland profile of Kulathupuzha remains unique,

Macromorphology of upland profiles

Table. 1-1

Location	Kulathupuzha				Nedumangad				Varkala			
Horizon No.	1	2	3	4	1	2	3	4	1	2	3	4
Horizon (Depth) (Cm)	(0-36)	(36.69)	(69-109)	(109-150+)	(0-18)	(18-5)	(57-108)	(105-150+)	(0-12)	(12-39)	(39-78)	(78-150+)
Topography	Hilly undulating				Undulating				Undulating			
Land use	Forest	..	..	..	Tapioca Cashew				Tapioca Cashew			
Drainage	Well drained	Well drained	Moderate	Moderate	Moderate	Moderate	Moderate	Poorly drained	Well drained	Well drained	Moderate	Slowly drained
Moisture in the profile	Moist	Moist	Moist	Moist	Dry	Moist	Moist	Moist	Dry	Dry	Moist	Moist
Depth of Water Table	15 M				25 M				25 M			
Evidence of erosion	Rill and gully erosion				Sheet and gully erosion				Sheet and gully erosion			
Presence of Salt/alkali	NIL	..	..	..	NIL	..	..	..	NIL	..	..	..
Colour	10 YR 3/3 Dark brown	10 YR 3/2 Dark Greyish	5 YR 4/6 Yellowish red	5 YR 4/6 Yellowish red	10 YR 4/3 Dark brown	10 YR 4/3 Dark brown	10 YR 5/6 Yellowish brown	5.[illegible] YR 4/6 Yellowish red	7.5 YR 4/4 Dark brown	5 YR 5/4 Raddish Brown	2.5 YR 5/6 Reddish	2.5 YR 5/6 Reddish
Texture	Loamy	Gravelly	Gravelly	Clayey	Gravelly Loam	Clay Loam	Clay Loam	Clay Loam	Gravelly Loam	Gravelly Sandy	Gravelly Sandy	Gravelly Clay
Structure	Granular	Weak Granular	Angular Blocky	Massive	Subangular blocky	Subangualr blocky	Subangular blocky	Subangular Blocky	Week medium crub	Weak granular	Subangular blocky	Massive
Plasticity	Non-plastic	plastic	plastic	Plastic	Non-Plastic	Non-plastic	Plastic	Plastic	Non-Plastic	Non-plastic	Non-plastic	Slightl plastic
Stickness	Slightly sticky	Slightly sticky	Sticky	Sticky	Slightly sticky	Slightly sticky	Sticky	Sticky	Slightly sticky	Slightly sticky	Slightly sticky	Sticky
Boundary	Gradual wavy	Gradual wavy	Gradual Smooth	Gradual Smooth	Clear	Wavy	Wavy	Wavy	Clear	Gradual Wavy	Wavy	Abrupt
Presence of roots	Abandant roots	Plenty	Trace	NIL	Plenty	Finer roots	Little	Nil	Plenty	Finer roots	Very Little	NIL
Permeability	Moderate	Moderate	Moderately	Slowly Permeable	Moderate	Moderate	Slowly Permeable	Slowly Permeable	Rapid	Moderately rapid	Moderately rapid	Moderate slow
Mottlings	::	..	..	Present	Present			Present	Present		Present	Present
Thickness of laterite Horizon	36 cm.	33 cm	40 cm	41 cm	18 cm	39 cm	51 cm	42 cm	12 cm	27 cm	39 cm	72 cm
Gravel Percentage	[illegible]	[illegible]	[illegible]	[illegible]								

Table 1.1 Macromorphology of Midupland profiles

Location	Kulathupuzha				Nedumangad				Varkala			
Horizon No.	1	2	3	4	1	2	3	4	1	2	3	4
Horizon Depth (Cm.)	(0–13)	(13–32)	(32–68)	(68–150+)	(0–23)	(23–56)	(52–87)	(86–150+)	(0–8)	(8–48)	(48–82)	(82–150+)
Topography	Hilly	..	..	..	Undulating	..	..	..	Undulating			
Land use	Forest				Tamarind, Tapioca				Coconut			
Drainage	Well drained	Well drained	Moderately drained	Poorly drained	Well drained	Well drained	Moderately drained	Poorly drained	Well drained	Moderate	Moderate	Very slowly drained
Moisture in the profile	Dry	Moist	Moist	Moist	Dry	Moist	Moist	Moist	Dry	Moist	Moist	Moist
Depth of Water Table	10 M				22M				12 M			
Evidence of erosion	Sheet and rill erosion				Sheet and rill erosion				Sheet erosion			
Presence of Salt/alkali	NIL				NIL				NIL			
	10 YR 4/3	10 YR 3/4	7.5 YR 4/4	5 YR 4/8	7.5 YR 4/4	7.5 YR 5/6	5 YR 4/6	5 YR 4/6	5 YR 3/4	2.5 YR 3/6	5 YR 4/6	5 YR 4/6
Colour	Very dark brown	Very dark yellowish brown	Dark brown	Yellowish red	Dark brown	Brownish	Yellowish brown	Yellowish red	Dark red brown	Dark brown	Yellowish red	Yellowish red
Structure	Granular	Granular	Angular blocky	Massive	Subangular blocky	Subangular blocky	Subangular blocky	Subangular blocky	Moderately crumb	Subangular blocky	Blocky	Massive
Texture	Gravelly Loam	Gravelly Clay Loam	Gravelly Clay	Clayey	Gravelly Sandy Loam	Sandy Clay Loam	Gravelly Sandy Loam	Clay Loam	Gravelly Sandy Loam	Gravelly Sandy Loam	Gravelly Sandy Loam	Sandy Clay Loam
Plasticity	Non-plastic	Slightly plastic	Plastic	Plastic	Non-plastic	Plastic	Plastic	Plastic	Non-plastic	Slightly plastic	Plastic	Plastic
Stickness	Slightly sticky	Sticky	Sticky	Sticky	Slightly sticky	Sticky	Sticky	Sticky	Slightly sticky	Slightly sticky	Sticky	Sticky
Boundary	Clear Smooth	Gradually wavy	Wavy	..	Clear Smooth	Gradually wavy	Gradually wavy	..	Smooth	Gradual wavy	Gradual wavy	Abrupt
Presence of roots	Abandant	Plently	Few roots	..	Abandant	Plently	Few roots	NIL	Plently	Few	very few fine roots	NIL
Premeability	Moderate	Moderate	Moderately slow	Slow	Moderate	Moderate	Moderately slow	Slow	Moderately rapid	Slow	Slow	Very slow
Mottlings	..	..	..	Present	..	..	Present	Present	..	..	Present	Present
Thickness of Plinthite layer	13cm	19cm	36cm	82cm	23cm	33cm	31cm	63cm	8cm	40cm	34cm	79cm
Gravel					71.6	78.5	68.4	77.1	71.3	75.4	80.0	79.5

with very dark brown in the surface layer to dark brown and yellowish brown in the subsurface layers while the midupland of Nedumangad and Varkala have dark brown surface soils and yellowish red sub surface layers.

Between profiles there is marked difference in soil colour of upland and midupland profiles of Kulathupuzha. However there is not much difference between the midupland and upland profiles of Nedumangad and Varkala.

Texture

In all the locations the upland profile is gravelly throughout (plate 2,5 and 7). The profiles contain 38 to 83 percent gravels. More than 75 percent of gravels are present in the profiles of Nedumangad and Varkala. However at Kulathupuzha location gravel content is noticed to be less than 60 percent. The texture of the profiles also are between gravelly sandy clay loam on one extreme to gravelly clay loam on the other in all locations. The surface of Varkala profile contains more than 75 percent (Table 1 and 2) gravel (plate 9). While the gravel content is less at Nedumangad and Kulathupuzha (plate 5, 2 and 14).

The midupland profiles in all locations have almost similar content of gravel as that of the upland profiles (plate 15). Location wise there is not much difference between upland and midupland profiles in their gravel content (plates 14 and 15).

Considering the comparative content of gravels in the surface soil in the Kulathupuzha and Nedumangad there is an increasing trend while at Varkala a decreasing trend down the profile is noticed. The texture of the midupland profile is gravelly sandy loam to gravelly clay loam in all the locations (Table 1.1 and 2.1).

Structure

In the case of the upland profile at Kulathupuzha, the depth-wise variation in structure is from granular to massive. At Nedumangad it is subangular blocky throughout the profile. The Varkala profile behaves unique. The surface has a weak medium crumb while the lowest layer has a massive structure (Table 1 and 1.1).

Stickness and Plasticity

The upland profiles of Kulathupuzha, Nedumangad and Varkala behave similarly, ie with friable, slightly sticky and non-plastic surface layer and a sticky and plastic lower layer. The midupland profiles also behave similarly as in the case of the upland profiles. Between profiles there is not much difference in all locations (Table 1 and 1.1).

Boundary

The horizon boundary of Kulathupuzha upland is gradually wavy to gradually smooth, While at Nedumangad it is clear to wavy and at Varkala it is clear to abrupt (Table 1).

Concretions/nodules

At Varkala profiles, angular to subangular ferruginous gravels of 2 to 5 mm diameter are noticed throughout the profiles. Black coloured nodules of 0.2 to 1 mm diameter are present in the surface of Kulathupuzha profile, While at Nedumangad similar nodules are intermediate in colour and size. Comparing the profiles in two physiographic positions of the same locations marked difference is not observed.

Mottling

Colour mottlings are noticed at Pallid zones of Varkala and Nedumangad, While it is rearely observed at lower layers of Kulathupuzha. At Kulathupuzha in the 3rd layer greyish white and white mottlings at erratic positions are observed (7.5 YR 6/8 Reddish yellow). At the lowest layer similar mottling (7.5 YR 6/6 Reddish yellow) is also observed. At Nedumangad upland in the third layer mottlings of yellow, pink and less reddish colours could be observed (5 YR 3/2 Dark reddish brow, 10 YR 6/6 Brownish yellow 2.5 YR 5/6 Red). At the bottom layer, red, yellow, white and pink mottlings observed (7.5 YR 7/5 Reddish yellow, 5 YR 4/4 Reddish brown, 2.5 YR 4/6 Red).

At Varkala upland red, pink and yellow mottlings are observed in the third layer (2.5 YR 3/6 Dark red, 2.5 YR 3/4 Dark reddish brown 10 YR 7/6 Yellow). At the fourth layer pink, mere yellow and less red mottlings are observed. (2.5 YR 4/8 red, 7.5 YR 6/8 Reddish yellow).

At Kulathupuzha midupland profile the third horizon has no significant mottlings. In the fourth layer however whitish and grey erratic mottlings as bigger pockets are observed. In these pockets fine sand to coarse sand sized sillminiticgneiss is observed (7.5 YR 7/6 Reddish yellow). At Nedumangad midupland profile yellow, yellowish red, pink, grey and white mottlings are observed in the third layer (7.5 YR 6/8 Reddish yellow, 7.5 YR 6/4 Light brown, 10 YR 7/8 Yellow, while in the fourth layer more pink, grey, yellow and less reddish mottlings are observed (7.5 YR 6/5 Light brown, 10 YR 6/6 Brownish yellow). At Varkala midupland profile in the third and fourth layer dark pinkish red and whitish yellow mottlings are observed (2.5 YR 3/6 Dark red, 7.5 YR 7/6 Reddish yellow).

<u>Thickness of laterite horizon</u> (Table 1 and 1.1)

At Kulathupuzha the soil is almost uniform throughout the profiles in the case of upland and midupland profiles except in the case of ferruginized sand pockets in the form of friable boulders (plates 3 and 4). Hard laterite layer is absent in both the cases. At Nedumangad in the upland profile the laterite layer is below a depth of 100 cm. In

In the case of midupland profiles it is clear and smooth wavy at Kulathupuzha and Nedumangad, while at Varkala it is smooth to abrupt (Table 1.1).

Comparing profiles in two topographical positions in the same location marked difference is noticed between the pairs of profiles in horizon boundary (Table 1 and 1.1).

Presence of roots

In the case of upland profiles the root activity is observed upto a depth of 75 cm, while in the case of midupland profiles it is seen upto 68 cm at Kulathupuzha, 56 cm at Nedumangad and 48 cm at Varkala. Between profiles there is not much difference in the extent of root activity at Kulathupuzha and Varkala, while at Nedumangad it is almost double in the midupland (Table 1 and 1.1)

Permeability

In the case of upland profiles permeability is moderate to slow at Kulathupuzha and Nedumangad while at Varkala it is rapid to moderately slow. In the case of midupland profiles at Kulathupuzha and Nedumangad it is moderate to moderately slow, while at Varkala it is moderately rapid to slow. Comparing the profiles in two topographical positions in the same location there is not much difference between pairs of profiles at Kulathupuzha and Nedumangad while there is marked difference in the permeability of the profiles at Varkala (Table 1 and 1.1).

the 4th layer bleached boulders are present. In the midupland profile at Nedumangad laterite layer is present below 100 cms. At Varkala the hard laterite layer is present at 78 cm depth in the upland profile and below 82 cm at midupland profile. Between locations Varkala upland profile is with highly ferruginized hard laterite layer while the midupland profile is Silica rich. At Nedumangad location in the upland profile laterite layer is dominantly ferruginous, and partly aluminous. At Kulathupuzha even though there is no specific laterite layer upto 150 cms, in the 3rd and 4th layers of both upland and mid upland profiles a tendency for laterite formation below 150 cms. At the laterite layers of upland and midupland profiles at Nedumangad and Varkala lies with in a depth of 2 metres which is soft when moist and hard when dry. Comparative order of increasing hardness (by feel) is as follows:- Nedumangad upland Varkala midupland Nedumangad midupland Varkala upland.

Topography

The sites of upland profiles at Kulathupuzha are mostly located in undulating terrain while those of Nedumangad and Varkala are on sloping land. Midupland profiles are also located in similar topography (Table 1 and 1.1).

Land Use (Table 1 and 1.1)

At Kulathupuzha soil profile is from a location under virgin vegetation, while at Nedumangad and Varkala the profiles

PROFILE DESCRIPTION

Information of the Site **Kulathupuzha upland**

a) Profile No. : 1

b) Soil Name : Laterite Soil

c) Higher category : Inceptisol

d) Date of examination : 21-11-1984

e) Author : R. Sankarankutty Nair

f) Location : 2 K.M. North of Kulathupuzha - On Trivandrum Shenkotta Road, District Quilon.

Latitude - 8°-55 and 8 - 96 North

Longitude- 77° 3 and 77° 4 East

g) Elevation : 240 meters M.S.L

h) Land form:

1) Physiographic position - Undulating terrain

2) Surrounding land form - Sloping

3) Microtopography - Gently sloping

4) Slope on which profile is located - Top of hill, gently sloping

i) Climate

Humid tropical climate; mean annual rain fall is 2961.6 mm which is distributed throughout year with a very little dry spell; the mean temperature ranges from 19°C to 35°C.

II. General information of the Soil

a) Parent material : Derived from sillimanitic gneiss and also associated rocks; colluvial deposit are also seen.

3

b) Drainage : Well drained with moderately slow internal permeability.

c) Moisture condition in the profile : Moist throughout.

d) Depth of ground water table : 15 meters

e) Presence of surface stone : Nil

f) Evidence of erosion : Rill and gully erosion.

g) Presence of salt or alkali : Nil

h) Human influence : Nil

Brief description of the profile

The profile is drained throughout, internal permeability is slow, gravel content increasing with depth. The influence of organic matter is high due to forest vegetation which imparts brownish black colour to the top layer, red colour increases with depth. The presence of roots are noticed in the lower horizons of the profile; crotovinas are seen in Bhorizion; ants are noticed in Bhorizion. Signs of laterisation is not very clear within the profile, boulders are also met with. Solum has got gravelly clay loam texture.

IV. Profile description

0 - 36 cm Dark brownish when moist (10 YR/3/3); loamy, granular structure; and slightly sticky non plastic; friable moist; abundant roots; gradually wavy boundary; well drained.

36 - 69 cm	Dark greyish brown (10 YR 3/2) when moist; gravelly clay loam; weak granular; slightly sticky but not plastic; friable moist; abundant roots, crotovinas present; gradual wavy boundary; moderate permeability.
69 - 109 cm	Yellowish red (5 YR 4/6) when moist; gravelly clay; angular and blocky; sticky and plastic; firm moist gradual smooth boundary; moderately slow permeability.
109 - 150 cm	Yellowish red (5 YR 4/6) on moist; clayey, massive; sticky and plastic; firm moist; slowly permeable; Big and soft boulders are present.

<u>Information of site</u> <u>Nedumangad upland</u>

a) Profile : 2

b) Soil Name : Laterite

c) Highest category of classification : Inceptisol

d) Date of Examination : 22-11-1984

e) Author : R.Sankarankutty Nair

f) Location : 3 K.M. from Nedumangad bus stand towards North. Near Kallampara river.

g) Elevation : 150 meters above M.S.L.

h) <u>Land form</u>

1) Physiographic position : sloping
2) Surrounding land form : sloping towards west
3) Microtopography : gently sloping
4) Slope on which profile is located : gently sloping

i) Land use : Topioca, Cashew, Jack, grass

j) Climate : Humid tropical climate. mean annual temperature ranges from 23.6°C to 30.9°C

Rainfall : 1798.17 mm

Dry season is from March to April-May.

II. General information of the soil

a) Parent material : Charnokites

b) Drainage : Moderately drained

c) Moisture condition of the profile : Moist below 25 cms

d) Depth of ground water table : 20 meters

e) Presence of surface stone : Nil

f) Evidence of erosion: Sheet and gully erosion

g) Presence of salt or alkali : Nil

h) Human influence : Confined to top 20 to 30 cms.

III. Brief description of the profile

The soils have been developed from gneissic parent material and are located in undulating rolling topography. Surface is dark grey brown and is gravelly loam. Accumulation of gray coloured Kaolinite can be noticed at random. The laterite gravels of irregular size can be seen from second layer.

IV. Profile description

0 - 18 cm	Dark brown (10 YR 4/3) moist; gravelly loam; subangular blocky; slightly sticky, nonplastic; friable moist; abundant roots, moderate permeability.
18-57 cm	Dark brown (10 YR 4/3) moist; Clay loam; Subangular blocky; slighty sticky; slightly plastic; firm moist; finer roots; wavy boundary, moderate permeability.
57-108 cm	Yellowish brown (10 YR 5/6) moist; clay loam; subangular blocky; sticky and plastic, friable moist, root influence sparce; slowly permeable.
108-150 cm	Yellowish red (5 YR 4/6) on moist, clayey; subangular blocky, sticky and plastic, firm moist; no roots; slowly permeable, no specific plinthitic layer observed with in 150 cms.

Information of the Site | Varkala upland

a) Profile No. : 3

b) Soil name : Laterite

c) Higher category : Inceptisol

d) Date of Examination : 30-8-1984

e) Author : R. Sankarankutty Nair

f) Location : 2 k.m. towards east from Varkala railway station ie. Cherukunnam.

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g) Elevation : 100 m above M.S.L.

Latitude - 8°-52' North

Longitude - 76°-52' East

h) Land form

1) Physiographic position - Gently sloping

2) Surrounding land form - Slightly sloping towards east

3) Microtopography - Flat

i) Slope on which profile is located : Gently sloping

j) Land use : Tapioca, Coconut and Jack

k) Climate : Humid tropical climate.

Mean annual temperature : 27°C

Mean annual rainfall : 876 mm

Dry season : November to March.

II. General Information on the soil

a) Parent material : Granitic rocks

b) Drainage : Moderately well drained

c) Moisture condition of the profile : Moist below 30 cms

d) Depth of ground water table : 25 m

e) Presence of surface stone, rock outcrops : Nil

Boulders present offers resistance to tillage operation.

f f) Evidence of erosion: Sheet erosion

g) Human influence : Confined to top 15 to 25 cms.

h) Presence of salt or alkali : Nil

III. Brief description of the profile

Shallow, moderately well drained reddish brown profile. Root influence is there at the top 30 cms plinthite layer is met at 131 cm with iron stone gravels. Gravels are present more in the surface. Soils are loose at top layers and uniform in colour. Plinthite is with aggregation of ferruginous gravels.

IV. Profile description

0 - 12 cm	Dark brown (7.5 YR 4/4) moist; gravelly loam; weak medium and coarse crumb; concretions are present; slightly sticky but not plastic; friable moist, roots abandant; wavy clear boundary; rapid permeability.
12-39 cm	Reddish brown (5 YR 5/4) moist; gravelly sandy clay loam; weak granular, slightly sticky and non plastic, slightly hard dry, few roots, tongued boundary; moderately rapid permeability.
39-78 cm	Reddish (2.5 YR/5/6) moist; gravelly sandy clay loam; subangular blocky; slightly sticky and slightly plastic, friable moist; roots are sparce; wavy boundary, moderately rapid permeability.
78-150 cm	Reddish (2.5 YR 4/6) moist, gravelly clay; massive structure, sticky and slightly plastic, friable moist, roots Nil, moderately slow permeability, Plinthite layer.

Information of the Site		Kulathupuzha mid upland
a) Profile No.	:	4
b) Soil Name	:	Laterite
c) Higher category	:	Alfisol
d) Date of examination	:	15-12-1984
e) Author	:	R. Sankarankutty Nair
f) Location	:	2 k.m. North of Kulathupuzha on Trivandrum Shenkotta Road, District Quilon. Latitude : 8° 55' and 8° 56' North Longitude : 77°.3 and 77.4' east.
g) Elevation	:	150 meter M.S.L.
h) Land form		
1) Physiographic position	:	Hills and Valleys are met with surface has got a convex shape.
2) Surrounding land form	:	Hilly
3) Microtopography	:	Gently sloping
i) Slope on which profile is location	:	Sloping.
j) Climate	:	Area enjoys a hot humid tropical climate. The annual rainfall is 2961.6 mm. The rainfall is received during almost all months. The mean temperature ranges from 19°C to 35°C. Dry season is very little met with in January to February.

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II. General information of the soil

a) Parent material : Derived from sillimanitic gneiss and associated rocks.

b) Drainage : Well drained with moderately slow internal permeability.

c) Moisture condition in the profile : Moist below 20 cms

d) Depth of ground water table : 20 meters

e) Presence of surface stone, rock etc. : Nil

f) Evidence of erosion : Rill erosion

g) Presence of salt or alkali : Nil

h) Human influence : Nil

Brief description of the profile

The profile is well drained with moderately slow internal permeability. The top layer is brownish black in colour and yellowish red colour increases with depth. The gravel also increases with depth. Presence of roots are seen even upto C horizon. Signs of laterisation is not evident. Boulders are seen within the profile at various stages of weathering. These soils have been developed under hot humid topical climate.

Profile description

0-13 cm — Very dark brown (10 YR 4/3) moist; loamy; moderately granular, slightly sticky but non plastic, when moist friable, roots abundant, clear smooth boundary, moderate permeability.

13-32 cm	Very dark yellowish brown (10 YR 3/4); gravelly clay loam; weak granular; sticky and slightly plastic; moist friable, fine roots present; gradually wavy boundary; moderate permeability. Soft subangular to rounded laterite boulders are observed. Top one's are more reddish than lower ones.
32-68 cm	Brownish (7.5 YR/4/4); gravelly clay; angular and blocky; sticky and plastic, firm moist; fine roots present; wavy boundary, moderately slow permeability. Subangular rounded soft laterite boulders are observed.
68-150 cm	Yellowish red (5 YR 4/8); clayey; massive; sticky and plastic; firm moist; roots nil, permeability is slow.

Nedumangad : Pazhakutty housing board site

<u>mid upland</u>

<u>Information of the Site</u>

a) Profile No. : 5

b) Higher category : Inceptisol

c) Soil Name : Laterite

d) Date of examination : 16-12-1984

e) Author : R. Sankarankutty Nair

f) Location : 3 km away from Nedumangad Bus Stand towards east. Pazhakutty housing board site.

g) elevation	:	75 m
		Latitude 8°-51' North
		Longitude 77°15' East

h) <u>Land form</u>

1) Physiographic position	:	Moderately sloping
2) Surrounding land farm	:	Sloping towards east
3) Microtopography	:	Flat to gently sloping
i) Slope on which profile is situated	:	Gradually sloping
j) Land use	:	Tapioca, Tamarind
k) Climate	:	The area enjoys a warm humid tropical climate. Seasons are controlled by South west and North east monsoon. Maximum precepitation is during June-July. Summer starts by February-March and lasts upto May. Eastern hilly region receives the maximum rainfall where elevation is upto 6000'. The mean rain fall is 1798.17 mm. The mean temperature ranges from 23°.6°C to 30.9°C.

II. <u>General information of the soil</u>

a) Parent material	:	Crystalline rocks of archean system which are intensely metamorphosed. Soils are mostly developed from gneissic rocks.
b) Drainage	:	Well drained with moderate internal permeability
c) Moisture condition of profile	:	Moist below 25 cms.
d) Depth of ground water table		22 meter
e) Presenre of a surface stone		Nil

f) Evidence of erosion : Sheet and gully erosion

g) Presence of salt or alkali: Nil

h) Human influence : Confined to top 20 to 30 cms.

III. Brief description of the profile

The surrounding physiography of the profile site is with undulating topography. The area enjoys a warm humid tropical climate. Colour of top layer is dark brown to yellowish brown, gravelly in texture. The colour changes from yellowish brown to yellowish red as depth increases. The soils are deep. Accumulation of Kaolinite is noticed. Surface layer contains much of orgnic matter due to the vegetation.

IV. Profile description

Depth	
0-23 cm	Dark brown (7.5 YR 4/4) moist; gravelly sandy loam, subangular blocky; slightly sticky and non-plastic; moist friable; roots abundant; crotovinas present; moderate permeability.
23-56 cm	Brownish (7.5 YR 5/6) moist; sandy clay loam; Subangular blocky; sticky and non plastic, moist firm; roots present; moderate permeability.
56-87 cm	Yellowish red (5 YR 4/6) moist; gravelly sandy clay loam, subangular blocky; slightly sticky and plastic; moist firm, crotovinas present; roots nil; moderately slow permeability. Laterite gravels are present.
87-160 cm	Yellowish red (5 YR 4/6) moist; clay loam; subangular blocky; slightly sticky and plastic; roots are absent; slowly permeable.

Varkala
Mid upland

Information of the site

a) Profile No.	:	6
b) Soil name	:	Laterite
c) Higher category	:	Inceptisol
d) Date of examination	:	12-2-1985
e) Author	:	R.Sankarankutty Nair
f) Location	:	4 km. away from Varkala railway station towards West. Near Papanasam area.
g) Elevation	:	12 Meter M.S.L. Latitude : 8°.52' North Longitude : 76° 56' East
h) **Land form**		
1) Physiographic position	:	Slighty sloping
2) Surrounding land form	:	Sloping towards west
3) Microtopography	:	Sloping towards west
i) Slope on which profile is situated	:	Gently sloping
j) Land use	:	Coconut
k) Climate	:	Warm humid tropical climate
Mean Annual rain fall is	:	876 mm
Mean annual temperature	:	27°C.

Dry spell is met with from November to March. Most of the rainfall is received during South west and North east monsoon season.

II. General information of the soil

a) Parent material : Granite rocks. Rocks belongs to the archean crystalline series, Varkala beds of tertiary age and recent allukvium and alluvial sands are the main geological formations of this area.

b) Drainage : Well drained externally with moderate internal permeability.

c) Moisture condition of the profile : Moist below 30 cms.

f) Evidence of erosion: Sheet erosion

g) Presence of salt or alkaly : Nil

h) Human influence : Confined to top layers only.

III. Brief description of the profile

Thickness of solum varies from 115 to 180 cms but is dominently between 125 to 140 cm. Texture varies from gravelly loam to sandy loam, but not gravelly throughout. Soil is moderately deep to very deep reddish brown laterite. Subsoil has got gravelly clay loam texture. A horizion is mostly loose as compaired to B. horizon. Ferruginous gravels lies with in the profile especially in the 3rd layer. Soil occurs mostly on landscapess characterised by flat topped hills and ridges.

IV. Profile description

Depth

0-8 cm Dark reddish brown (5 YR 3/4); moist; gravelly sandy loam; moderately crumb; slightly sticky and non plastic; moist friable, roots abundant; smooth boundary, moderately rapid permeability.

8-48 cm	Dark brown (2.5 YR 3/6)moist; gravelly sandy loam; sub angular blocky; slightly sticky and slightly plastic; few roots; gradual wavy boundary; slowly permeable.
48-72 cm	Yellowish red (5 YR 4/6 moist); gravelly sandy loam; sub angular blocky; sticky and plastic; firm; few fine roots; boundary wavy; slowly permeable, ferrugenous gravels present.
72-150 cm	Yellowish red (5 YR 4/6) sandy clay loam; massive; sticky and plastic, moist firm; no roots; abrupt boundary; very slow permeability.

RESULTS

Granulometric composition

Gravels (Table 1 and 2.1)

In all the locations the upland profile is highly gravelly throughout. The profiles contain 38 to 83 percent gravels. More than 75 percent gravels are contained in Varkala and Nedumangad upland profiles and the next is Kulathupuzha which contains 60 percent gravels. The surface soil of Varkala is gravelly containing more than 75 percent gravels. Gravel content is found to decrease from Varkala to Nedumangad and from Nedumangad to Kulathupuzha. The mid upland profiles in all locations behaves almost similarly in gravel content to that of the respective upland profiles. Locationwise significant difference between profiles of upland and midupland in their gravel content could not be noticed. Considering the comparatively higher content of gravel generally observed an increasing trend is further noticed with depth in all locations though the pattern is not definite.

Coarse sand

The content of coarse sand in various horizons of the profiles is presented in Table 2 and 2.1. In the upland profiles the coarse sand is more in the surface layer. The Varkala profile contained more coarse sand followed by the

PHYSICAL PROPERTIES

Table - 2

Granulometric Composition (Upland) percent by weight

Location	Kulathupuzha UP				Nedumangadu UP				Varkala Up			
Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (in cm)	0-13	13-32	32-68	68-150+	0-36	36-69	69-109	109-150+	0-12	12-39	39-98	98-150+
Gravel	38.1	45.0	58.4	60.2	75.7	64.6	68.1	77.1	78.1	81.5	83.2	82.0
Coarse sand	35.1	22.0	21.7	22.1	31.1	28.3	25.5	23.4	40.1	38.1	30.2	27.0
Fine sand	10.0	8.1	9.0	10.2	22.5	21.1	22.2	19.0	22.1	24.0	20.5	12.1
Silt	10.0	9.1	10.2	11.0	15.0	15.4	14.1	12.1	15.0	12.2	14.3	13.0
Clay	38.0	54.0	50.0	48.0	29.0	32.2	34.5	42.1	20.0	22.2	28.1	42.1

Table - 2.1

Granulometric Composition (Mid upland) percent by weight

Location	Kulathupuzha Up				Nedumangadu				Varkala			
Profile No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (in cm)	0-36	36-69	69-109	109-150+	0-23	23-56	56-87	87-150+	0-8	8-48	48-72	72-150+
Gravel	40.2	42.5	57.5	59.1	76.2	72.5	68.4	77.1	71.2	75.4	80.0	79.5
Coarse sand	33.2	29.2	30.8	20.5	30.2	26.1	29.3	28.1	32.0	20.2	14.1	12.1
Fine sand	12.0	10.3	9.1	8.9	18.2	20.3	15.3	14.5	30.0	25.3	15.0	15.1
Silt	11.0	12.1	10.5	10.1	17.0	15.1	12.0	10.6	14.1	14.3	10.8	9.4
Clay	37.0	42.0	41.0	52.7	30.4	33.5	40.0	43.0	19.8	36.1	57.1	55.7

surface horizons of Kulathupuzha and Nedumangad profiles. The content of coarse sand is found to decrease with depth in all locations.

In the midupland profiles also the pattern of distribution of coarse sand is similar to that of upland profiles. But the content of coarse sand is more in upland profiles than the midupland profiles.

Fine sand

The fine sand content is indicated by data in Table 2 and 2.1. Irrespective of the location it has been observed that the content of fine sand decreased with depth. The content of fine sand is more at surface layers of Varkala upland followed by Nedumangad and least at Kulathupuzha. A similar trend has been recorded in the mid upland profiles also. Between locations the midupland profiles contained greater quantities of fine sand than the respective upland profiles except at Nedumangad, where the upland contained more fine sand.

Silt

The distribution of silt in various soils profiles is indicated in Tables 2 and 2.1. It can be seen that silt content decreases with depth in almost all locations except at Kulathupuzha upland where maximum silt content has been observed at the fourth layer. Between locations much variation in silt content has not been observed.

Clay

The results on the content of clay in the various horizons of the profiles under study are presented in Tables 2 and 2.1. Irrespective of the location it is observed that the clay content increased with depth. But at Kulathupuzha upland profile a regular pattern of increase or decrease could not be discovered. Except at Kulathupuzha the content of clay has been observed to be more in the midupland profiles than the respective upland profiles. Varkala midupland recorded the maximum amount of clay at the fourth layer though the clay content at surface layers is low.

Textural ratios

Fine sand/coarse sand

Textural ratios of the profiles are given in Table 3 and 3.1. The fine sand by coarse sand ratio of the Kulathupuzha upland ranges from 0.36 in the surface and 0.46 in the lowest layer. While at Nedumangad it ranges from 0.72 in the surface to 0.81 in the lowest layer and at Varkala it is 0.55 in the surface and 0.45 in the lowest layer. There is an increase with depth at Nedumangad and Kulathupuzha while it decreases with depth at Varkala.

In the mid upland profiles of Kulathupuzha it ranges from 0.28 at surface to 0.39 in the lowest layer. While at Nedumangad it lies between 0.60 in the surface and 0.52 in the lowest layer and at Varkala it ranges from 0.93 in the surface to 1.24 in the lowest layer. At Kulathupuzha the ratio increases with depth while at Nedumangad and Varkala alternate increase and decrease pattern is shown with depth.

At Kulathupuzha location between profiles considerable differences in the pattern of these ratios could not be noticed. However tendency for a narrowing of this ratio could be observed for the Nedumangad location. The profiles at Varkala behave uniquely in that the ratio widens at all depths in the midupland situation.

<u>Silt/clay ratio</u> (Table 3 and 3.1)

At Kulathupuzha upland profiles it lies between 0.29 at surface and 0.19 in the lowest layer while at Nedumangad it lies between 0.52 in the surface and 0.29 at the lowest layer and at Varkala it is 0.75 in the surface and 0.31 in the lowest layer. The ratio shows an increasing trend irrespective of the locations. Between locations the ratio gets widened in the order of Kulathupuzha Nedumangad Varkala.

A similar trend is recorded in the mid upland profiles also in all locations. Between upland and mid upland profiles

Table - 3 Upland

Textural ratios of the soil samples

Location	Kulathupuzha				Nedumangadu				Varkala			
Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth(cms)	0-13	13-32	32-68	68-150+	0-36	36-69	69-109	109-150+	0-12	12-39	39-98	98-150+
Fine sand / Coarse sand	0.36	0.35	0.30	0.43	0.72	0.74	0.87	0.81	0.55	0.63	0.68	0.45
Silt / Clay	0.29	0.28	0.25	0.19	0.52	0.45	0.40	0.29	0.75	0.55	0.51	0.31
Sand+Silt / Clay	1.50	1.20	1.20	0.70	2.30	2.00	1.80	1.30	3.80	3.30	2.30	1.24

Table - 3.1 Mid upland

Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (Cms)	0-36	36-69	69-109	109-150+	0-23	23-56	56-87	87-150+	0-8	8-48	48-72	72-150+
Fine sand / Coarse sand	0.28	0.37	0.41	0.39	0.60	0.76	0.52	0.52	0.93	1.25	1.05	1.24
Silt / Clay	0.26	0.17	0.21	0.23	0.29	0.28	0.25	0.19	0.71	0.40	0.20	0.17
Sand+Silt / Clay	1.45	0.73	0.80	0.86	2.15	1.84	1.41	1.24	1.80	1.60	0.70	0.68

of Kulathupuzha and Nedumangad much difference in the ratio could not be observed. However, between the locations Nedumangad and Varkala marked difference in the ratio has been seen.

<u>Clay ratio</u> (Table 3 and 3-1)

In the case of upland profiles at Kulathupuzha it lies between 1.5 in the surface and 0.7 in the lowest layer; at Nedumangad it lies between 2.3 in the surface and 1.3 in the lowest layer; while at Varkala it is 3.8 in the surface and 1.2 in the lowest layer. A narrowing of the ratio with depth is noticed in all locations.

In the case of midupland profiles at Kulathupuzha it lies between 1.5 in the surface and 0.86 in the lowest layer and at Nedumangad it is 2.15 in the surface and 1.24 in the lowest layer while at Varkala it lies between 1.8 in the surface and 0.68 in the lowest layer.

As in the case of upland a narrowing of the ratio with depth is noticed in all locations in the case of midupland profiles also. Between the profiles at Kulathupuzha and Nedumangad considerable differences in the clay ratio could not be observed. Here also Varkala behaves unique in that significant narrowing of ratio from upland to midupland is noticed.

Aggregate analysis (Table 4 and 4.1)

Irrespective of the locations the percentage of aggregates above 0.25 mm is found to decrease with depth. In all locations except Kulathupuzha midupland profile, the aggregate percentage at the fourth layer is more than that of the third layer. The percentage of aggregate is in the decreasing order Varkala Nedumangad Kulathupuzha. Between profiles there was not much difference in all the locations.

Mean weight diameter (Table 4 and 4-1)

The mean weight diameter is found to decrease with depth except at Nedumangad and Varkala upland. At Nedumangad upland and midupland there is not much difference in mean weight diameter with in the profile. A similar observation has also been recorded for the Varkala upland profile also. It is in the decreasing order Varkala midupland Nedumangad upland Varkala upland and Nedumangad midupland Kulathupuzha profiles

Single value constants

a) Bulk density (Table 5 and 5.1)

The bulk density is found to increase with depth irrespective of the location. Between locations Varkala midupland recorded the highest values followed by Varkala upland. There is not much difference between profiles at Nedumangad as well as Kulathupuzha. But the least values are recorded at Kulathupuzha.

Table - 4   **Structural indices of the soil samples**

Aggregate analysis by wet sieving

Upland profiles

Location	Kulathupuzha				Nedumangadu				Varkala			
Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (in cm)	0-13	13-32	32-68	68-150+	0-36	36-69	69-109	109-150+	0-12	12-39	39-98	98-150+
Aggregate % above 0.25 mm	82.80	69.70	67.80	69.50	86.50	84.60	82.90	84.50	85.60	79.40	77.10	83.20
Men weight diameter	2.10	1.40	1.60	1.60	2.00	2.00	1.90	2.00	1.80	1.70	1.70	1.80
Organic matter%	2.40	1.26	1.02	0.72	1.36	0.95	0.90	0.69	1.20	0.90	0.45	0.39
Clay %	38.00	54.00	50.00	48.00	29.00	32.20	34.50	42.10	20.00	22.20	28.10	42.10

Table - 4.1

Mid upland profiles

Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cms)	0-36	36-69	69-109	109-150+	0-23	23-56	56-87	87-150+	0-8	8-48	48-72	72-150+
Aggregate % above 0.25mm	78.20	71.20	67.00	56.70	81.00	79.40	75.90	77.90	87.10	85.30	78.40	81.10
Mean weight diameter	2.00	1.70	1.60	1.40	1.80	1.70	1.70	1.80	2.00	2.00	1.70	1.80
Organic matter %	2.30	1.70	1.10	0.69	1.90	1.14	0.57	0.30	1.20	0.40	0.14	0.12
Clay %	37.00	42.00	41.00	52.70	30.40	33.50	40.00	43.00	19.80	36.10	57.10	55.70

b) Particle density (Table 5 and 5-1)

The particle density is found to increase with depth in both upland and midupland except in the case of Kulathupuzha upland, where the particle density is found to decrease with depth. In general, the particle density recorded at upland profiles is more than that recorded at midupland profiles. Between locations it is in the decreasing order Varkala upland Varkala mid upland Nedumangad upland Nedumangad midupland Kulathupuzha upland Kulathupuzha mid upland.

c) Porosity (Table 5 and 5-1)

The porosity does not show any regular trend. But a slight increase in porosity has been recorded with depth in certain profiles.

Water holding capacity (Table 5 and 5.1)

The water holding capacity is found to increase with depth in both upland and midupland profiles. But at Kulathupuzha upland and midupland profiles the maximum value has been recorded on the third layer and the fourth layer, showed a decreasing trend as compaired to the 3rd layer.

Between locations the Kulathupuzha upland and mid upland have recorded higher water holding capacity for the samples in various horizons followed by Nedumangad and least

Table - 5

Upland

Single value constants

Location	Kulathupuzha				Nedumangadu				Varkala			
Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cms)	0-13	13-32	32-68	68-150+	0-36	36-69	69-109	109-150+	0-12	12-39	39-98	98-150+
Bulk density	1.12	1.15	1.15	1.13	1.20	1.23	1.15	1.22	1.24	1.26	1.23	1.30
Particle density	2.03	2.04	1.89	1.84	1.97	2.06	2.17	2.75	2.15	2.15	2.18	2.75
Porosity %	44.12	65.74	50.94	48.40	42.00	46.00	47.50	46.20	41.82	45.00	42.00	59.70
Water holding capacity %	36.80	38.80	45.10	44.10	29.70	34.20	36.00	40.40	28.90	33.40	30.70	30.70
Organic matter %	2.40	1.26	1.02	0.72	1.36	0.95	0.90	0.69	1.20	0.90	0.45	0.39
Clay %	38.00	54.00	50.00	48.00	29.00	32.20	34.50	42.10	20.00	22.20	28.10	42.10
Moisture %	11.00	9.00	10.00	10.00	3.00	5.00	7.00	9.00	3.00	3.00	7.00	8.00

Table - 5.1

Mid upland

Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cms)	0-36	26-69	69-109	109-150+	0-23	23-56	56-87	87-150+	0-8	8-48	48-72	72-150+
Bulk density	1.12	1.70	1.16	1.18	1.13	1.19	1.19	1.26	1.53	1.37	1.74	1.90
Particle density	1.83	1.95	1.96	1.96	1.62	1.83	2.16	2.51	2.29	2.30	2.30	2.38
Porosity %	42.00	46.00	47.50	46.20	43.00	47.00	49.70	47.00	40.84	43.03	34.57	53.69
Water holding capacity %	36.00	38.30	45.10	44.10	33.00	33.40	38.50	39.40	20.90	22.40	22.30	22.80
Organic matter %	2.30	1.70	1.10	0.69	1.90	1.14	0.57	0.30	1.20	0.40	0.14	0.12
Clay %	37.00	42.00	41.00	52.70	30.40	33.50	40.00	43.00	19.80	36.10	57.10	55.70
Moisture %	11.00	10.00	10.00	9.00	7.00	8.00	8.00	8.00	3.00	3.00	4.00	5.00

at Varkala. Between profiles of the same location there was not much difference in the water holding capacity.

Moisture percentage at collection

The moisture percentage is found to increase with depth in all the locations except Kulathupuzha upland and mid upland. At Kulathupuzha the moisture percentage is found to decrease with depth. This may be due to the showers received on the day of collection of samples. Though these have not much significance, the relevance is only removal of moisture prior to micromorphological examination. This removal has to be in a manner that will not bring about drastic changes in micromorphology.

CHEMICAL PROPERTIES

pH (Distilled water method)

The pH of profile soil samples are provided in Table 6 and 6.1. It is observed that irrespective of the location the pH decreases with depth. Between profiles much difference in pH has not been observed.

pH (KCl solution)

As in the case of pH (H_2O) it is seen that pH (KCl) decrease with depth in all locations.

Table - 6

Chemical properties of the soil samples — Upland

pH and conductivity

Location	Kulathupuzha				Nedumangadu				Varkala			
Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cms)	0-13	13-32	32-68	68-150+	0-36	36-69	69-109	109-150+	0-12	12-39	39-98	98-150+
pH (distilled water)	5.50	5.20	5.30	5.20	5.60	5.00	4.80	5.00	5.5	5.30	5.30	5.20
pH (kcl solution)	4.10	4.00	3.90	4.00	4.00	3.90	3.80	3.80	4.20	4.30	4.00	4.10
pH (NaF solution)	9.80	10.70	11.20	11.20	9.70	9.80	10.70	10.90	10.70	11.10	11.10	11.30
Conductivity	0.80	0.60	0.40	0.40	0.84	0.58	0.55	0.71	0.45	0.47	0.29	0.36

Table - 6.1

Mid upland

Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cms)	0-36	36-69	60-109	109-150+	0-23	23.56	56-87	87-150+	0-8	8-48	48-72	72-150+
pH (distilled water)	5.60	5.30	5.20	5.20	5.30	5.00	4.80	5.10	5.50	5.20	5.10	4.90
pH (Kcl solution)	4.10	3.90	3.90	4.00	3.90	3.70	3.70	3.90	4.30	4.00	4.20	4.20
pH (NaF solution)	9.10	9.60	10.50	10.60	9.40	9.90	10.10	10.30	9.60	9.90	9.90	9.60
Conductivity	0.18	0.15	0.15	0.69	0.67	0.14	0.15	0.10	0.43	0.50	0.39	0.67

pH (NaF solution)

An increase in pH is observed in all cases irrespective of the locations except in Varkala midupland where though the trend is same, the maximum value has been obtained at horizon No. 2 and 3.

Conductivity (Table 6 and 6.1)

The general tendency is a decrease in conductivity with depth irrespective of locations except Nedumangad upland and Varkala midupland. In the latter two cases the conductivity increases and then decreases followed by an increase in the fourth layer. In general the higher values for conductivity are obtained at upland than the respective midupland profiles.

Organic carbon and organic matter

The percentage of organic carbon and organic matter is presented in Table 7 and 7.1. It is observed that the content of organic matter decreases with depth irrespective of the locations. Between locations organic matter content is more at Kulathupuzha followed by Nedumangad and least at Varkala. Between profiles the organic matter content is more at midupland profiles in all locations except at Varkala. At Varkala, the upland profile recorded more amount of organic matter. The organic carbon also followed the same pattern of distribution in all locations.

Organic matter, clay and C.E.C. of the soil samples

Table - 7

upland

Location	Kulathupuzha				Nedumangadu				Varkala			
Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cms)	0-13	13-32	32-68	68-150+	0-36	36-69	69-109	109-150+	0-19	19-39	39-98	98-150+
Organic matter %	2.40	1.26	1.02	0.72	1.36	0.95	0.90	0.69	1.20	0.90	0.45	0.39
Clay	38.00	54.00	50.00	48.00	29.00	32.20	34.50	42.10	20.00	22.20	28.10	42.10
C.E.C.	10.00	9.00	8.20	8.50	4.00	5.00	5.50	5.20	4.80	5.00	4.90	5.50

Table - 7.1

Mid upland

Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depty (cms)	0-36	36-69	69-109	109-150+	0-23	23.56	56.87	87-150+	0-8	8-48	48-72	72-150+
Organic matter %	2.30	1.70	1.10	0.69	1.90	1.14	0.57	0.30	1.40	0.40	0.14	0.12
Clay	37.00	42.00	41.00	52.70	30.40	33.50	40.00	43.00	19.80	36.10	57.10	55.70
C.E.C.	9.50	8.20	8.00	7.90	5.00	6.20	6.10	6.00	4.20	4.10	5.20	5.70

C.E.C (Table 7 and 7.1)

The C.E.C. is found to increase with depth in all locations except Kulathupuzha. At Kulathupuzha the C.E.C. is found to decrease with depth. Between locations the C.E.C. decreased in the order of Kulathupuzha Nedumangad Varkala. Between profiles there is not such difference in all locations. But Nedumangad midupland profile showed a higher value as compared to that of Nedumangad upland profile.

Total Iron

Tables 9 and 9.1 present the distribution of Total iron in the various soil profiles. A general pattern of decrease in iron content with depth is seen. The upland profiles contain higher amounts of iron than the respective midupland profiles in all locations except at Varkala. At Varkala location difference could not be noticed between profiles. The content of iron decreases in the order of Varkala mid upland Varkala upland Nedumangad upland Nedumangad midupland Kulathupuzha upland Kulathupuzha midupland.

Exchangeable calcium:

The Exchangeable Calcium content of various horizons of the profiles are presented in Table No.9 and 9.1. It has been observed that the exchangeable calcium decreased with

Chemical properties of the soil samples N,P,K

Table - 8

Upland

Location	Kulathupuzha				Nedumangadu				Varkala			
Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cms)	0-13	13-32	32-68	68-150+	0-36	36-69	69-109	109-150+	0-12	12-39	39-98	98-150+
Total N%	0.46	0.35	0.21	0.16	0.24	0.19	0.19	0.16	0.21	0.19	0.16	0.16
Total P%	0.10	0.06	0.03	0.03	0.08	0.08	0.07	0.06	0.06	0.06	0.03	0.03
Total K%	0.16	0.11	0.12	0.94	0.03	0.04	0.03	0.08	0.06	0.03	0.03	0.36

Table - 8.1

Mid upland

Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cms)	0-36	36-69	69-109	109-150+	0-23	23-56	56-87	87-150+	0-8	8-48	48-72	72-150+
Total N%	0.50	0.38	0.21	0.16	0.27	0.21	0.16	0.13	0.21	0.16	0.13	0.16
Total P%	0.11	0.08	0.05	0.04	0.11	0.06	0.05	0.07	0.07	0.06	0.05	0.04
Total K%	0.16	0.12	0.13	0.10	0.16	0.13	0.14	0.12	0.07	0.09	0.06	0.04

Upland

Table - 9

Chemical properties of the soil samples, Iron, calcium and magnesium

Location	Kulathupuzha				Nedumangadu				Varkala			
Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cms)	0-13	13-32	32-68	68-150+	0.36	36-69	69-109	109-150+	0-12	12-39	39-98	98-150+
Total Fe_2O_3%	5.900	5.500	4.000	5.800	8.200	7.000	7.500	7.800	8.500	7.700	7.200	7.300
Calcium %	0.194	0.074	0.047	0.047	0.180	0.048	0.020	0.260	0.141	0.101	0.079	0.072
Magnesium %	0.130	0.082	0.050	0.090	0.320	0.310	0.040	0.150	0.083	0.107	0.075	9,951

Table - 9.1

Mid upland

Location	Kulathupuzha				Nedumangadu				Varkala			
Horizion No.	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cms)	0-36	36-69	69-109	109-150+	0-23	23-56	56-87	87-150+	0-8	8-48	48-72	72-150+
Total Fe_2O_3%	5.500	5.000	5.100	5.200	6.800	6.500	6.300	6.300	8.800	7.700	7.200	7.300
Calcium %	0.206	0.079	0.063	0.044	0.128	0.090	0.047	0.067	0.068	0.051	0.048	0.051
Magnesium %	0.135	0.031	0.025	0.029	0.032	0.036	0.054	0.023	0.088	0.039	0.104	0.103

depth in all locations. In general the midupland profiles have a higher exchangeable calcium content than the correspon-ding upland profiles irrespective of locations except at Varkala. At Varkala however the upland profile contained high amount of exchangeable calcium. Between locations the content is more at Kulathupuzha followed by Nedumangad and least at Varkala.

Exchangeable Magnesium

Table 9 and 9.1 presents the pattern of distribution of exchangeable magnesium at different locations. In general, magnesium content is found to decrease with depth in all locations except Varkala. At Varkala the lower layers conta-ined higher amounts of magnesium in the midupland profiles. In the upland profile the second layer contained maximum amount of exchangeable magnesium. Between locations the mid upland profiles contained higher amounts of magnesium than the respective upland profiles.

Total nitrogen

The total nitrogen content is represented in Table No. 8 and 8.1. It has been observed that irrespective of the location, the nitrogen percentage decreases with depth. The percentage of nitrogen decreases in the order of Kulathupuzha midupland Kulathupuzha upland Nedumangad midupland Nedumangad upland Varkala upland Varkala midupland.

Table - 10 Upland

Comparative table of organic matter, clay, iron, calcium, magnesium and C.E.C. of the soil samples

Location	Kulathupuzha				Nedumangadu				Varkala			
Horizion	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cm)	0-13	12-32	32-68	68-150+	0-36	36-69	69-109	109-150+	0-12	12-39	39-98	98-150+
Clay %	38.000	54.000	50.000	48.000	29.000	32.200	34.500	42.100	20.000	22.200	28.100	42.100
Organic matter %	2.400	1.260	1.020	0.720	1.360	0.950	0.900	0.690	1.200	0.900	0.450	0.390
Iron %	5.900	5.500	4.000	5.800	8.200	7.000	7.500	7.800	8.500	7.700	7.200	7.300
Calcium %	0.194	0.074	0.047	0.047	0.180	0.048	0.020	0.260	0.141	0.101	0.079	0.072
Magnesium %	0.130	0.082	0.050	0.090	0.320	0.310	0.040	0.150	0.083	0.107	0.075	0.051
C.E.C. meq/ 100 g soil	10.000	9.000	8.200	8.500	4.000	5.000	5.500	5.200	4.800	5.000	4.900	5.500

Table - 10.1 Mid upland

Horizion	1	2	3	4	1	2	3	4	1	2	3	4
Depth (cm)	0-36	36-69	69-109	109-150+	0-23	23-56	56-87	87-150+	0-8	8-48	48-72	72-150+
Clay %	37.000	42.000	41.000	52.700	30.400	33.500	40.000	43.000	19.800	36.100	57.100	55.700
Organic matter %	2.300	1.700	1.100	0.690	1.900	1.140	0.570	0.300	1.200	0.400	0.140	0.120
Iron %	5.500	5.000	5.100	5.200	6.800	6.500	6.300	6.300	8.800	7.700	7.200	7.300
Calcium %	0.206	0.079	0.063	0.044	0.128	0.090	0.047	0.067	0.068	0.051	0.048	0.051
Magnesium %	0.135	0.031	0.025	0.024	0.082	0.036	0.054	0.023	0.088	0.039	0.104	0.103
C.E.C. meq/ 100g soil	9.500	8.200	8.000	7.900	5.000	6.200	6.100	6.00	4.200	4.100	5.200	5.700

Phosphorus

total. ?

The available phosphorus status of the various horizons of the profile are presented in Table No.8 and 8.1. The phosphorus content decreases with depth in all locations. The content of phosphorus has been observed to be higher at Kulathupuzha followed by Nedumangad and least at Varkala. Between profiles noteworthy differences in Phosphorus content could not be observed.

Potassium

The potassium content of the profiles is presented in Table No.8 and 8.1. The distribution in general does not follow a regular pattern. Between locations a higher value is recorded at Kulathupuzha followed by Nedumangad with the lowest content at Varkala. Between profiles the midupland profiles of Nedumangad and Varkala contained more potassium than the respective upland profiles. There is not much difference between profiles at Kulathupuzha.

Minerology

Salient findings on minerological composition of the fine sand fraction are presented in Table 10 and 10.1. In general both heavy and light minerals generally associated with soils are lower in the lowest horizon, than in the surface horizons irrespective of the topographical site or

3

(Table 11) **Mineralogy of fine sand fraction**

(Kulathupuzha Upland)

	Light Minerals				Heavy Minerals			
Profile No.	Quartz	Titanium	Iron group	Ferro calcium	Mica group	Accessary minerals (Zircon)	Quartz	Iron group
1 (0-13) cm	25-50%. Angular to subangular rounded and broken. No coating mica 5 to 10%	Feldspar 5 - 10% Routile 2 - 5% occational distribution of tournalin (2 to 5%) Zircon 5 to 2%		Nil	0.2 to 2%	0.5 to 2%	Occational Angular broken.	Flagioclays feldspar 2 to 5% Opaque minerals occational.
2 (13-32) cm	Subangular, subrounded quartz 25-50%. Organic matter granules rare. Biotite frequent. No coating over the quartz.	Feldspars frequent 5 - 10%. Opaque mineral - occational.		-	-	-	10-15% Rarely coated with Limonite angular quartz present.	Feldspars & Magnetite present. Organic matter granules rare. Opaque minerals 2 to 5%.
3 (32-68) cm	Coated quartz 5 to 10%. Lemonite and Goethite. Broken quartz feldspars (without coating) 25 to 50%. Mica-rare, Opal-rare.	garnet - rare 5 to 2% Opidote -0.5-2% Pureminerals- Nil.		-	Black mica 5 -10% conspiquous	Nil	High relief quartz subangular subrounded 5 to 10%	Feldspars - 10 to15% Magnetite - rare. Garnet - rare.
4 (69-150) cm	Coated quartz- Abandant, angular to subangular. Frequent coating of Limonite and goethite. Organic matter rare.	Feldspars - Abandant coated with limonite & goethite Mica - Frequent garnet } epidot } 0.5 to 2% phlogophyte		-	Biotite 5 - 10% chalcidon 0.5 - 2%.	-		Garnet - rare. 0.5-2%. High relief Opaque minerals-rare. <u>Pure mineral</u> goethite - rare. Feldspars - rare.

Cont:

(Table 11)

MINERALOGY OF FINE SAND FRACTION
(Nedumangad Upland)

Light Minerals					Heavy Minerals			
Profile No.	Quartz	Titanium	Iron group	Ferro calcium	mica	Accessary (Zircon)	Quartz	Others (Titanium)
1 Depth (0-36) cm	5-10% Epidot 0.5-2% 2 to 5% quartz coated with iron Quartz are weathered, broken subangular and rounded	2.5%	2-5% (Magnetite, Haematite & Limonite)	Nil	Nil	2-5%	5-10%	5-10% iron (Allgrains are subangular & subrounded.
2 (36-69) Cm	25-50% coated with Limonite and haematite. Zircon 0.5 to 2%	2.5%	2-5% (Limonite, Magnetite and haematite)	-	-	5-10%	5 to 10 (15 to 20?)	5-10% (Magnetite is (dominent). Striking feature is dominance of iron minerals and coating of quartz. Epidet 10 - 15% present.
3 (69-109) Cm	25-50% (2 to 5% high relief quartz) Zircon 2-5%. Quartz coated with Limonite epidot present. Feldspar 2 to 5%.	2.5%	2 to 5% (Magnetite dominant)	.5 to 2%	Nil	0.5 to 2%	15-20%	Magnetite, Haematite, Limonite present. Broken quartz of varying size packed.
4 (109-150) Cm	25 -50% minerals are subangular & subrounded. Packing of broken quartz. 50% of quartz are iron coated	0.5 to 2%	.5 to 2% (coating of Limenite 80% Haematite 20%)	-	-	2-5%	Broken quartz (25-50%), rounded & subrounded 25% coated with Haematite, 10% with Limonite	Magnetite, Haematite and Limonite present.

(Cont...)

Mineralogy of fine sand fraction
(Varkala Upland)

(Table 11)

Light Minerals | **Heavy Minerals**

Profile No. 5		Quartz	Titanium	Iron group	Ferro calcium	mica	Accessary (Zircon)	Quartz	Others Titanium
Depth (0-12) cm	I	10-15%	10-15%	10-15% (Magnetite)	0.5 to2%	Nil	2 to 5%	5-10%	5-10% (Weathering feldspars 2 - 5%).
Horizion (12-39) cm	2	0·5 - 15%	2-5%	2-5%	Nil	Nil	2 to 5%	2-5%	15 to 25% (even 50%)
39-78 cm	3	Zircon 0·-15%. Iron coated quartz felds-par 20%	0.5-2%	10-15%	Nil	Nil	5-10%	2-5% Feldspars 2% which are iron coated	2 - 5%
78-150+ cm	4	25-50% Zircon 0.5 to 2%	2-5%	Quartz with iron coatings.	Nil	Nil	2-5%	5-10% iron	Feldspars 2% (Iron coated quartz feldspar)

(Table 11.1) MINERALOGY OF FINE SAND FRACTION (Kulathupuzha Midupland)

Light Minerals					**Heavy Minerals**			
Pro-file No.	Quartz.	Tita-nium group.	Iron group.	Ferro calcium.	Mica.	Accessary minerals.	Quartz.	Others.
1 Depth (0-36) cm	Broker, angular, subrounded quartz coated witn Limonite & Haematite 25-50%. Organic matter present. Discon-tinuous marginal humas deposit.	2-5%.	2-5% angular magnetite zircon 2-5%.	Nil.	Nil.	2 to 5%.	Angular broken flaky tubular 25to 50%.	Fe-10 to 15% (Magnetite-10%) (Others - 5%) Feldspars - 2-5% coated with Limonite 2 Haematite.
2 (36-69) cm	25-50% Bigger quartz of high relief, 2-5% coating with magnetite.	2-5%.	2-5% Magnetite of big and high relief coating M-L-H.	Nil.	Nil.	2 - 5%	Flaky angular quartz 25-50% coating L-H M-5-10%.	
3 (60-109) cm	25-50% More tubular Zircon - 2 to 5% no coating.	- mica 0.5 to 2%.	5 to 10% M - H - L.	Nil.	0.5 to 2%	Zircon .5 to 2% with L-coating	2 to 50% broken and fiat.	
4 (109-150) cm	25-50% Quartz of varied size and relief. Fiat, Slender, typical coating L - H. No organic matter.	Nil mica 0.5 to 2%.	5 - 10% H - M-L.	Nil.	0.5 to 2%	**Zircon** 0.5 to 2% with limonite coating	Abandant (25-50% coating L-H	Goethite, limonite - rare Hamatite-rare Epidote-rare

(Contd.)

Mineralogy of fine sand fraction

(Table 11.1)

(Nedumangad Midupland)

Light Minerals					Heavy Minerals			
Profile No. 4	Quartz	Titanium	Iron group	Ferro calci-ums	Mica	Accessary minerals	Quartz	Others
1	2	3	4	5	6	7	8	9
1 Depth (0-23) cm	25 - 50% Zircon - 0.5 to 2% (high relief) Quartz are broken Epidote - 0.5 to 2%	10 to 15%	25 - 50% (M - 40%) (H - 8%) (L - 2%)	Nil	Nil.	5 - 10%	25-50% complete broken quartz coating L-H. M-5-10%	Epidote 2-5%
2 (23-56) cm	15 - 25% Feldspar - 5-10% Flaky, broken coated with L-H. Sub rounded & subangular	0.5 to 2%	2-5% Magnetite	Nil	Nil	2-5%	2-5% bigger, high relief quartz 25 to 50% coating H-L-M 2 to 5%	
3 (56-87) cm	25-50%. Broken, subangular, subrounded. Feldspar 5 to 10% coating L-H.	0.5-2%	Broken mica 0.5-10% of high relief	Nil	Nil	Broken felds-par 2-5% Zircon 2-5%	15 to 20% coating L-M- subangular& subrounded.	
4 + (87-150) cm	25-50% coating. L-H Broken, angular and subangular	5-10%	5 to 10% (M-8%) (Others-2%)	Nil		2-5%	25-50% broken, angular and subangular. Round to subrounded M. (opaque)	

(Contd...)

(Table 11-1)

Mineralogy of fine sand fraction

(Varkala Midupland)

Profile No.6	Light Minerals: Quartz	Titanium	Ferro group	Mica group	Accessary minerals	Heavy Minerals: Quartz	Ferro group
Depth (0-8 cm)	Quartz Abandant. Angular to sub-angular-have coating of L. High relief quartz. Mica-rare		Feldspars frequent coating of L. Opaquem-inal-rare	-	-	Abandent Feldspars-broken chalsidon rare. Quartz & Feldspars are on equal proportion	High relief opaque minerals frequent M-L-G 5 to 10% Tournalin, garnet, Dionite, epidote, Flogophite RARE
(8-48) cm	Very abundant Angular to subangular Feldspar-Abandant Olivine-rare Irratic coating on high relief quartz & Feldspars with GL.		Opaque minerals - rare epidote-rare guarnet-rare chalsidonic-rare Mica-rare	-	-	Augularto subangular broken quartz-irratic coating of Limonite Rare Lithorelix.	Opaque mineral of high relief sub-angular and sub-rounded is very frequent. garnet & epidote-rare. Haematite-rare- Pure minerals-L Feldspars-rare
(48-72) cm	Angualr to sub-angular rarely rounded quartz-abandant to very abandant. Rare irratic coating of high relief quartz only by-L		Opal-rare high relief opaque minerals-rare Zircon-rare Feldspar-frequent garnet-rare	Biotite-rare		High relief subangular subrounded-abandant to very abandant.	
(72-150 + cm)	Quartz-Abandant to very abandant. Coating of L on broken quartz qrains opaque minerals-rare		Feldspars occational to frequent	Zircon-rare		High relief quartz grains subangular to subrounded	frequent to very frequent

Opaque minerals

Subangular to subrounded high relief-Abandant coating -M -H - L rare goethite

Note. More opaque grains than quartz, garnet few flogo-phite epidote-0.5 to 2%

M-Magnetite H-Haematite, L- Limonite

geographical location of the profile. Iron bearing minerals like magnetite, limonite, haematite, goethite were appreciably high in the upland profiles irrespective of the locations. Occurrence of limonite was a characteristic feature of the lower horizons except at Kulathupuzha where alone haematite is found to be the dominant mineral throughout the profiles.

Ferromagnesium minerals are found to be absent in the upland profiles while traces are observed in the midupland profiles in all locations. Comparatively more zircon and quartz are found to be present in the upland profiles than the mid upland profiles at Nedumangad and Varkala. At Kulathupuzha, Zircon is rarely noticed in both profiles. Comparatively more mica, feldspars and opaque minerals are found in the Kulathupuzha profiles. They are comparatively low at Nedumangad and least at Varkala. These profiles are low in easily weatherable minerals, except Kulathupuzha where it is present frequently.

Considering the content of quartz and zircon in the profiles the order of weathering are Kulathupuzha midupland Kulathupuzha upland Nedumangad midupland Varkala mid upland. Nedumangad upland Varkala upland.

The mineral grains of upland profiles except Kulathupuzha is angular to subangular, while in midupland profiles it is subangular to sub-rounded. At Kulathupuzha in both

(Table 12) Micromorphology (upland)

Location	Kulathupuzha				Nedumangad				Varkala			
Profile No.	1	2	3	4	1	2	3	4	1	2	3	4
Colour of plasma.	Reddish brown.	Yellowish red.	Reddish brown.	Yellowish red.	Yellowish red.	Yellowish red.	Reddish brown.	Opaque to reddi-brown.	Opaque to reddish brown.	Yellowish brown to opaque.	–	Reddish.
Soil fabric	Vosepic.	Vosepic to skelsepic.	Vosepic to Argillaspic.	Skelsepic to vosepic.	Skelsepic to vosepic.	Skelsepic.	Skelsepic to vosepic.	Skelsepic to vosepic.	Insepic.	Vosepic.	Vosepic.	Arillasepic to Vosepic.
R.D.P.	Porephyric.	Chlamydomorphic.	Chlamydomorphic.	Chlamydomorphic.	Chlamydomorphic.	Chlamydomorphic.	Chlamydomorphic.	Chlamydomorphic.	Chlamydomorphic.	Chlamydomorphic.	Chlamydomorphic.	Chlamydomorphic.
NRDP Coarser/ Finer Fraction.	Finer.	Finer.	Coarser.	Coarser.	Finer.	Finer.	Finer.	Finer.	More finer than coarse fraction.	More finer fraction.	Finer.	Finer.
Voids.	Chambers, channels.	Vughs, vessicles.	**Vughs, vessicles.**	Planner packing.	Vessicles & vughs.	Vughs.	Vughs & Vessicles.	Vughs.	Vughs vessicles & channels.	Vessicles vughs channels.	Vughs.	Vughs & Vessicles.
Humus.	Present.	Present.	Present.	Present.	Present.	Present.	....	....	Present.	Present.	Nil.	Nil.
Aggregate		Plasmafied humus aggregates.	Plasmafied humus aggregates.							Present O.M.	Sesquan aggregate.	
Chlamydo morphic coatings.		Noticed.								Humus coating on grains present.		
Litho-relics												
Argillan.	Ferri-argillan.	Ferran organ.	Ferran.		Ferri-argillan.	Ferri-argillan.	Ferri-argillan.	Ferri-agrillan.	Ferri-argillan.		Ferri-argillan.	
Special observation	Nil	e										
Nature of skeleton.		Subangular sub-[illegible]	Sub-angular opaque.		Sub-angular.	Angular to sub-angular.	Rounded to sub-rounded.		Rounded.	Sub-rounded.		Rounded sub-angular.

(Table 12.1)

Micromorphology : Midupland

Location	Kulathupuzha				Nedumangad				Varkala			
Profile No.	1	2	3	4	1	2	3	4	1	2	3	4
Colour of plasma.	Brownish yellow.	Yellowish brown.	Brownish yellow.	Opaque to yellowish brown.	Brownish yellow.	Bleached yellowish brown.		Yellowish.	Reddish brown.	Reddish brown.	Dense reddish brown.	Reddish brown.
Soil fabric.	Argillasepic vosepic.	Argillasepic to skelsepic.	Vosepic.	Voskelsepic.	Vosepic to skelsepic.	Vosepic to skelsepic.	Argillasepic to skelsepic.	Vosepic to Argillasepic.	Skelvosepic.	Skelsepic.	Skelsepic.	Argillasepic.
RDP NRDP.		Porephyric.									Pore phyro skelic.	
Coarser/ Finer Fraction.	Finer.	Finer.	Finer.	Finer.	Coarser.	Coarser.	Finer.	Finer.	Coarser.	Coarser.	Coarser.	Coarser.
Voids.	Vughs and vessicles.	Vessicles.	Vughs/ channels & chambers.	Vughs, vessicles, channels.	Vughs, vessicles, channels, chamber.	Vughs and Vessicles.	Vughs.	Vughs, vessicles.	Vughs and vessicles.	Vughs and vessicles.	Vughs and vessicles.	Vughs and vessicles.
Humus.	noticed.	Noticed. (rare)			Present.	Present.	Nil.	Nil.	Plasmafied organic matter.	Plasmafied organic matter.	O.M. present inangular spaces.	
Aggregates.	Ferri-organ aggregates.		Coalised micro aggregates.			Nil.	Nil.	Nil.	Aggregates of sesquan.	Ferri organ.	sesquioxide rich.	Sesquioxide rich.
Chlamydo morphic coatings.										Present	Present	
Lithorelics. Argillan.	Ferri-argillan.		Ferri-argillan.	Ferri-argillan.	Ferri-organ.	Ferri-organ.	Illuial ferri-argillan.	Ferri-argillan.	Ferri-argillan.	Ferri-organ.	Iron stained.	Ferri-argillan.
Special observation.		Concretion Skelsepic to argillasepic		Kaolinte accumuts in voids	High relief magnitute							
Nature of skeleton.	Sub-angular sub-rounded.	Sub-angular sub-rounded.	Sub-angular.	Sub-angular sub-rounded.	Sub-angular sub-rounded.	sub-rounded.		Sub-round to rounded.	Sub-rounded to rounded.	Sub-rounded to rounded.	Sub-rounded to rounded.	Rounded to sub-rounded.

profiles the skeletal grains are angular to sub-angular. The coating of iron oxide and fillings of fractured grains are of the increasing order. Kulathupuzha midupland Kulathupuzha upland Nedumangad midupland Varkala midupland Nedumangad upland Varkala upland.

The find sand minerology of ferruginised sand boulders present at both profiles at Kulathupuzha contain comparatively sand to coarse sand sized quartz (angular), free silica, haematite and ferran cutans. These are observed to be more abundant in the upland profile.

Micromorphology

Detailed micromorphological description of the soil profiles are presented in tables 12 and 12.1.

In the case of upland profiles the colour of the plasma is reddish brown in the surface (plate 16, 17) to yellowish red in lower layers (plate 22, 23) at Kulathupuzha while at Nedumangad it is yellowish red to reddish brown (plate 24, 25, 30, 31) and at Varkala it is reddish brown to red (plate 32, 33, 38, 39).

In the case of midupland profiles at Kulathupuzha (plate 40, 41, 47, 48) and Nedumangad (plate 49, 50, 55, 56) it is brownish yellow to yellowish brown while at Varkala it is reddish brown (plate 57, 58, 63, 64) throughout the profile.

The plasmic fabric is vosepic in the surface (plate 16, 17) to skelsepic at lowest layer (plate 22, 23) of the upland profile of Kulathupuzha At Nedumangad. It is, skelsepic to vosepic and rarely isotic and aespic (plates 24 to 31). At Varkala it is asepic, randomly argillasepic and vosepic (plate 32 to 39). In the case of midupland profiles at Kulathupuzha vosepic to skelsepic (plate 40 to 48) at Nedumangad it is vosepic to skelsepic in the surface (plate 49, 50) and skelvosepic in lowest layer (plate 55, 56). At varkala it is skelvosepic in the surface (plate 57, 58) and argellasepic in lowest layer (plate 63, 64).

In the case of upland profiles an intertextic and chlamydomorphic specific related distribution pattern is observed at Kulathupuzha (plate 16 to 23). In the field the soil has a friable consistence (plate 3). The cutans occur as bridges between sand grains. At Nedumangad profiles the plasma tends to aggregate and a specific kind of specific related distribution pattern termed as agglutanic is observed (plate 24 to 31).

At Varkala the cutans occur as complete coatings as bridges around the skeleton grains, giving a dermatic to intertextic specific related distribution pattern (plate No.32 to 39). It is more clear in the argillic horizion which has a friable consistence in the field, to as bridge around the skeleton grains, giving a dermatic to intertextic specific related distribution pattern (plate No.32 to 39).

In the case of midupland profiles the specific related distribution pattern is (plate 40 to 48) similar to respective upland profile at Kulathupuzha (plate 16 to 23). At Nedumangad the specific related distribution pattern is intertextic in the upper layers (plate 49, 50, 51, 52) to dermatic in the lower layers (plate 53 to 56). The dermatic specific related distribution pattern is more clear in the 4th layer (plate 55, 56) as in the case of upland profile at Varkala (plate 38, 39). At Varkala an agglutanic specific related distribution pattern is seen (plate 57 to 64) Even though the profile is deep with a 'pale' clay distribution, horizions with argillan are not very deep. Here the tendency for the formation of an argillic horizion over an oxic material is clearly obserted (plate 62 to 64).

Considering the upland and midupland profiles of Nedumangad and upland profiles of Varkala argillic horizion continues to the saprolite. At most a similar observation is recorded in the upland profile of Nedumangad. Such observation is not clear at Kulathupuzha and midupland profiles at Varkala.

In the case of upland profiles at Kulathupuzha finer fraction is more in the surface (plate 16, 17) and more coarser fraction in the lower layers (plates 20 to 23). At Nedumangad the surface soil is with finer fraction (plate 24, 25) and coarser in the middle (plate 27 to 29) and finer in the lower layers (plate 30, 31). Similar observation is also recorded at Varkala (plates 32, 33, 38, 39). The distribution pattern of coarser and finer fraction in the midupland profiles is similar to the respective upland profiles.

Voids: In the case of profiles of Kulathupuzha, chambers, channels and vesicles are the dominant voids in the surface layer (plates 16, 17, 40 and 41) and it is dominantly vughs and vesicles in the lower layers (plate 22, 23, 47 and 48). While at Nedumangad vughs and vesicles present in all the layers (plate 24 to 31 and 44 to 56) vesicles are comparatively more in the upper layers (plate 24-29, 49-52). At Varkala vughs, vesicles and channels are present in the upper layer (plate 32, 33, 57, 58) and vughs and vesicles are present in the lower layers (plates 38, 39, 63, 64).

Humus: Plasmafied humus is present in the surface layers of all the upland profiles inspective of locations (plates 16, 17, 24, 25, 32, 83). They are present as micro and macro aggregates comparatively more at Kulathupuzha upland profile (plates 16 to 17). In the second and third layer humus is present as organ sesquan to organ ferran irrespective of the location (plates 18, 19, 26, 27, 34, 35). In the case of midupland profile similar observation is recorded at Kulathupuzha and Nedumangad only (plates 40 to 43 and 49 to 52). Presence of humus even in the surface layer of midupland profiles of Varkala as clear cutans is noticed (plate 57, 58). Chlamydomorphic related distribution pattern is observed only in the upper layers of both profiles of Kulathupuzha (plates 16 to 19 and 40 to 43) which gives a spodic feature observable in the podzols of temperate regions.

Lithorelics: With regard to the presence of lithorelics, it is absent in all the profiles, irrespective of locations except Kulathupuzha profiles, where fine sand sized sillimanitic gneiss pieces are observed in the lower layers (plates 22, 23, 47 and 48).

Cutan: The observation of mineral cutans present was very difficult at Kulathupuzha locations. Organs are present dominantly in the upper two layers of the profiles at Kulathupuzha (plates 16 to 19, 40 to 43). They are present in combination to ferran to sesquan in the lower layers [(3rd and 4th) (plates 20, 23, 45 to 48)]. At Nedumangad organs are present in the surface layer of midupland profile only (plate 49, 50). They are present in combination with sesquan in the upper layers of upland profile at Nedumangad (plates 24 to 27). At Varkala organs in combination with sesquan is present in the surface layer only (plate 32, 33 and 57, 58). Ferriargillan is the characteristic feature of the laterite layer present in the upland profile at Varkala (plate 30 to 39), midupland profile at Nedumangad (plate 53 to 56) upland profiles at Nedumangad (plate 28 to 31) midupland profiles at Varkala (plate 63 to 64) in the decreasing order.

<u>Skelton grains</u>: Skelton grains (quartz) present in all the profiles are coated with free iron oxide in all the profiles irrespective of the location. They are sub-angular in surface layer (plates 16 to 19, 24 to 27 and 32 to 35) to angular in lower layers (plates 20 to 23, 28 to 31 and 36 to 39) of the upland profiles in all locations. Almost similar observation is recorded in the midupland profiles at Kulathupuzha (plate 40 to 48) and Nedumangad (plate 49 to 56) while the midupland profile at Varkala is having sub angular to subrounded skeleton grains (plate 57 to 64). The presence of weatherable mineral like hornblende, feldspar etc. are observed comparatively more in the profiles at Kulathupuzha (plates 16 to 23 and 40 to 48) and rare at Varkala (plates 32 to 39 and 57 to 64) and least at Nedumangad (plates 24 to 31 and 49 to 56).

Quartz grains present are broken and fractured, filled with free iron is present in the increasing order upland profile at Nedumangad midupland profile of Varkala mid upland profile of Nedumangad and upland profile at Varkala. They are absent or rare even at lower layers of Kulathupuzha (plates 23, 33 and 47, 48). Another important observation in the present study is that more unweathered angular biotite mica and angular opaque minerals are present at Kulathupuzha only (plates 16 to 23 and 40 to 48). Though opaque minerals are present rarely in other profiles, they are in the decreasing order Nedumangad midupland (Plates 49 to 56) Nedumangad upland (plate 24 to 31) Varkala midupland (plate 57 to 64) Varkala upland (Plate 32 to 39). The opaque minerals present are dominantly sillimanite at both the profiles of Kulathupuzha (Plates 16 to 23 and 40 to 48) magnetite at Nedumangad and Varkala upland (Plates 24 to 31 and 32 to 39), while in the midupland profiles of Varkala (Plate 57 to 64 and Nedumangad (Plates 49 to 56) presence of magnetite is observed.

DISCUSSION

DISCUSSION

In Kerala laterite soils are found to occur in many physiographic positions ranging from highland to lowland. In this study the genesis of laterite soils in the upland and midupland positions alone have been studied.

The genesis of laterite soils at upland and midupland positions is found to be different. In order to assertain and bring out atleast some of the genetical processes involved in the formation of these two distinct types of laterites, macro and micromorphology, finesand mineralogy and physico-chemical properties of the three upland and mid-upland profiles from Kulathupuzha, Nedumangad and Varkala at two physiographic positions have been studied.

Macromorphology:

The unique dark brown colour of Kulathupuzha profiles are due to high organic matter content (Plates 3 and 6). Between profiles uniformity in colour observed at Nedumanged and Varkala is due to a lesser content of organic matter, lesser difference in the degree of hydration and oxidation of some of the minerals present. Observed difference in soil colour between profiles at Kulathupuzha could also be due to differences in the quantity of Organic matter present in them (Tables 4 and 4.1).

Irrespective of the locations the upland and midupland profiles are gravelly throughout, (Plates 14 and 15), may be due to higher gradient, more exposure, precipitation and insolation. Differences exhibited between profiles (Upland and midupland) could also be due to differences in their texture mainly induced by topographical features permitting erosion of higher particles from higher topographical situations and their greater deposition at lower situations.

The granular structure observed at Kulathupuzha profiles are due to high organic matter and lesser content of sesquioxide. The massive structure observed in the laterite layer of Nedumangad and Varkala sites are due to higher content of sesquioxide and ferruginous clay.

Irrespective of the locations except at Kulathupuzha the midupland profile is stickier and plastic because of higher content of clay and lesser content of organic matter.

The gradual wavy to gradual smooth horizion boundary observed in the Kulathupuzha profile (Plates 1,3 & 4) is because of the lesser differences in gradient and comparable organic matter content and lesser degree of human influence. The clear to wavy and clear to abrupt horizion boundary observed at Nedumangad and Varkala (Plates 6, 8, 10 & 13) are due to low content of organic matter (Plates 6 and 8) more clay translocation and greater human influence (Plate 11).

The observation of root activity is in the increasing order Varkala > Nedumangad > Kulathupuzha, may be due to content of organic matter in the increasing order at Varkala > Nedumangad > Kulathupuzha, and clay content in decreasing order Kulathupuzha > Nedumangad > Varkala. It may also be attributed to comparative granular structure in the increasing order Varkala > Nedumangad > Kulathupuzha.

Irrespective of the profiles moderate permeability observed in the upper layers in all locations is due to the porous nature of the horizions. Moderately slow to slow permeability observed in plinthite layer or pallied zone is due to massive structure.

The presence of angular to subangular ferruginous gravels of 2 to 5mm diameter in the surface (Plates 9 and 12) and through out the profiles observed (Plates 14 and 15) at Varkala is a typical feature of ferruginous latosols of the tropics, is due to more exposure to heavy rainfall and insolation. It can also be attributed to comparatively higher content of iron in the insitu laterite of the site. Black coloured 0.2 to 1 mm diameter nodules are present in the surface of Kulathupuzha, Profile (Plate 2). This may be due to sillimanitic gneiss parent material. At Nedumangad however it is intermediary in colour and size (Plates 5 and 7).

More over the gravels of Nedumangad are concretionary in nature (Plates 5,7,14 and 15).

Mottling: (Plates 3,4,6,8,10 and 13)

Colour mottling are observed in the pallid zones of Varkala and Nedumangad laterite profiles and rarely in the Kulathupuzha profile especially in the lower layers. This may be due to higher water table and ferruginous clay and lesser lateral drainage. A higher content of clay and occurrence of a massive structure with the observed moderately slow drainage at Varkala may partly account for the different types and greater coverage of mottling.

Thickness of Pallid Zones: (Plates 3,4,6,8,10 and 13)

A laterite layer is significantly absent at Kulathupuzha while it is present at Nedumangad and Varkala. Typical plinthite layer is observed at Varkala profiles (especially upland) and the midupland profile at Nedumangad. The layer is both massive and ferruginized. At Nedumangad it is comparatively friable and not so hard. This may be due to the comparatively higher content of sand and organic matter in the layer. The presence of a plinthite layer comparatively at a lower depth at Nedumangad rather than at Varkala is due to lesser organic matter, greater degree of clay translocation and lower depth of occurrence of water table at Varkala. The plinthite layer of Varkala is pisolitic and ferruginized while at Nedumangad they consist of only ferruginous clay and sand.

Higher water table and nearness to river is the reason for sandy friable pallid zones of Nedumangad and sandy lower layers at Kulathupuzha. As the profiles sites of Kulathupuzha are located in undulating terrain and at Nedumangad and Varkala sloppy, it experienced rill to gully erosion extensively. The difference in the extent of erosion observed at Kulathupuzha profiles sites are little due to thicker natural vegetation and more organic matter of the profile by phytocycling (Plates 1,3 and 4), moderately at Nedumangad is due to moderate levels of organic matter and cultivation (Plates 6 and 8). Comparatively more erosion noticed at Varkala is due to undulating topography, low content of organic matter and cultivation (Plates 10,11 and 12).

PHYSICAL PROPERTIES

Granulometric Composition (Plates 14 and 15 and Tables 2 and 2.1)

The percentage of gravels in the upland profiles are higher than the respective midupland profiles of the three locations. The profiles at Varkala are distinctly gravelly throughout, while at Nedumangad the gravels are present in the surface horizons only and are concretionary in nature, within the profile it is plinthitic material. As in the case of Varkala at Kulathupuzha also concretionary gravels are present at both the surface and at lower layers. In addition non-concretionary gravelly material also occurs at lower layers. Lateral migration of finer fractions to the foot slope and consequent accumulation of gravelly material in the back slope may be one of the causes for the comparatively higher content of gravels recorded in the profiles at upland. This is in agreement with the findings of Subramonia Iyer (1979). The maximum content of gravel observed at Varkala may be due to the exposure of the soil consequent to erosion and subsequent hardening. Such observations have been made in other catenary sequences by Biswas and Gawande (1962), Sivaraja Singham et al (1962), Gupta et al (1974), Rengaswamy et al (1978) and Subramania Iyer (1979).

The finer fraction represented by clay+silt decreases with depth in all laterite profiles studied. Between the midupland laterite profiles and upland profiles the clay content in the upland profile is invariably higher. Consequently fractions between 2 mm and 0.02 mm are less in the upland profiles as compared to midupland profiles. Thus in the upland profile there is higher percentage fraction above 2 mm and below 0.2 mm. This is in agreement with the observation reported by Subramonia Iyer (1979).

<u>Textural ratios</u> (Table 3 and 3.1)

Fine sand to coarse sand ratio of surface layer in the upland laterite profiles are of the order 0.36, 0.72 and 0.55 respectively for Kulathupuzha, Nedumangad and Varkala. There is a marked decrease in the ratio between profiles at Varkala and the ratio narrows down at Nedumangad and Kulathupuzha which may be due to the gradient difference between profiles of respective locations. Similar observation is recorded by Ruhe and Walker (1968), Murali, <u>et al</u> (1978) and Subramonia Iyer (1979).

<u>Silt/Clay ratio</u>:

Silt/clay ratio of the surface layer in the upland profiles are 0.29, 0.52 and 0.75 respectively at Kulathupuzha, Nedumangad and Varkala, while the same ratio for midupland profiles are 0.26, 0.29 and 0.71 respectively. In the midupland profiles they are comparatively less than that of the respective upland profiles. The difference is marked at Nedumangad, whereas at Kulathupuzha and Varkala the differences in the ratio are narrower. This may be due to comparatively well drained condition of the profiles observed at Nedumangad.

The clay ratio is found to be very nearly the same between the profiles at Kulathupuzha and Nedumangad while at Varkala marked difference is observed between profiles which is an indication that the midupland profile is a colluvial laterite from the materials of finer fractions of adjoining upland profile. Considering all the textural ratios marked difference is observed at Varkala, while at Nedumangad the difference is observed only in the silt/clay ratio. Similar observations are also made by Gopalaswamy (1969) and Subramonia Iyer (1979) for the laterite and lateritic soils of Kerala.

Single value constants:

Single value constants are presented in tables 5 and 5.1. These values obtained for upland profiles are comparatively higher than those of the respective midupland profiles. It increases with depth in all profiles. The observed difference between the profile at each location and within the profile can be related mainly to their clay content. Similar results have also been reported by Venugopal (1969), Harikrishnan Nair (1973) and Hassan (1977) and Subramonia Iyer (1979) in the laterite and red soils of Kerala.

<u>Aggregate analysis and comparative evaluation of water stable aggregates:</u>

The data of the structural indices namely percentage of aggregates more than 0.25 mm diameter and mean weight diameter of the aggregates of the different layers of the profiles are provided in the tables 4 and 4.1.

A higher percentage incidence of aggregates with more than 0.25 mm diameter and mean weight diameter observed in the upland profiles than the respective midupland profiles, of Nedumangad and Kulathupuzha. At Varkala the midupland profiles records higher values for the above structural indices when compared to respective upland profiles. The observed difference in the structural indices between locations, between profiles and with in profiles can be related to difference in their iron content, clay and organic matter content (Tables 7 and 7.1).

From the table it is clear that at Varkala the influence of aggregating agent may be in the increasing order clay content , iron content and , organic matter. Tamhane and Dutta (1965) and Subramonia Iyer (1979) have reported a similar observation. From the present study it can be observed that irrespective of locations the structural indices of laterite soils are influenced by clay, iron and organic matter content.

CHEMICAL PROPERTIES

Soil reaction: (Table 6 and 6.1) The soils are all acidic in reaction. pHw varies between the range 4.8 to 5.6 in the upland and midupland profiles. Between profiles irrespective of locations the pH determined by all the three methods do not differ significantly. From these range value of pH it can be assumed that these soils are with sufficient exchangeable aluminium and percent of base saturation is low. The lack of difference observed by the pHw may be due to the reserve of dominant mineral kaolinite. The observed difference in pHk (KCl 1N solution) is little, which is one to one and a half unit less than the respective pHw, indicating the presence of significant amounts of either exchangeable or complexed slowly exchangeable aluminium. The pHs (1N sodium flouride solution) is found to be greater than respective pHw indicating that the soil has a net positive charge due to dominance of the exchangeable complex by hydrous iron oxides, the rise in pH is due to displacement of OH by flouride.

Cation exchange capacity (Table 10 and 10.1)

Statistical analysis of the factors contributing C.E.C. of soils revealed that in the case upland profile samples 90.5 per cent contribution of soil C.E.C. is governed by their clay, organic matter, iron, calcium and magnesium content ($Y = 17.26 - 1.66 x 5 + 16.97 x_4 - 0.026 x_1 - 0.19 x_2 + 0.51 x_3$) ($R = 0.95$, level of significance 1%) While in the case midupland profile samples these factors contribute 87.5 per cent of the soil C.E.C. ($Y = 6.97 - 0.59 x_5 + 2.34 x_2 - 8.09 x_3 + 10.08 x_4 + 0.02 x_1$) ($R = 0.94$ at 1% level of significance).

The profiles do not exhibit any definite pattern either within or between locations. This may be due to the lesser difference in the content of clay, organic matter, iron, calcium and magnesium. At Kulathupuzha midupland C.E.C. uniquely decreases with depth.

Inspite of the higher content of clay all the profiles exhibit low C.E.C. values, which necessarily is due to the occurrence of Kaolinitic type of clay minerals. The low C.E.C. of these profiles irrespective of the locations can be attributed to the characteristically predominant Kaolinite and the dilution effect there on by the free oxides in the profile. Satyanarayana and Thomas (1962) working with Malabar laterites, Menon and Mariakulandai (1957) working on red and laterite soils of Tamilnadu, Venugopal and Koshy (1976), Subramonia Iyer (1979) working in laterite and red soils of Kerala got similar results.

Comparatively, calcium content is higher than the magnesium content except in the midupland profiles of Varkala, where lower layer has been observed to contain higher magnesium content than the content of calcium. Their influence on C.E.C. of the soil is highly significant.

Calcium and Magnesium

Calcium and Magnesium content of all the profiles are comparatively lower due to the inherently lower content of Calcium and Magnesium containing minerals in the parent material and heavy precipitation consequent to which those which occurred have been weathered and lost. Calcium and Magnesium contents follows a definite pattern in the profiles irrespective of locations. They both decrease with depth except in the midupland profiles of Varkala alone where the magnesium content is found to increase with depth. This may be due to the nearness to the sea coast and the possibility that the lateritic material itself has been formed from the soil material deposited alluvially on marine formations.

Iron

Total content of iron in the various profiles is presented in table 9 and 9.1. The total iron content of upland profile in general is higher than the corresponding midupland profiles in all the three locations. Iron content of upland profile at Nedumangad and both of the upland and midupland at Varkala behaves almost similarly. On the basis of their total iron content the profiles can be placed in the increasing order midupland Kulathupuzha > upland Kulathupuzha > Midupland Nedumangad > Upland Nedumangad > Upland Varkala and > midupland Varkala. These observed differences in iron content and its consequent refelction on soil colour (Table 1, 1.1, 9 and 9.1) and other properties relying on iron content such as depth of occurrence of plinthitic layer, hardness of the plinthitic layer (Plates 10 and 37) etc. are depended on the extent and degree of laterisation.

Profiles at Nedumangad and Varkala are highly ferruginous when compared to that of Kulathupuzha ie. the process of ferruginization is at its maximum at Varkala, intermediary at Nedumangad and least at Kulathupuzha. With regard to the content of total iron a decrease with depth is observed. This decrease is more clear in the upland profile of Varkala and midupland profile of Nedumangad.

It is significant to point out the close parallelism between vegetation and extent of laterisation as observed in the three sets of profiles from nearly the same latitude but from different physiographic locations and vegetations. Thus the profiles with increasing laterisation from Kulathupuzha to Nedumangad and Varkala represents the typical three major physiographic regions namely forest, midlands and coastal regions. The vegetation also typically changes in these three regions. Thus the forests of Kulathupuzha are the typical deciduous forest type while the Nedumangad area represents the regions in the midland with foot hills of the Western ghats with tree crops of the plantation type deliberately planted in formerly forested areas. The coastal areas of the Varkala region represents the typical coastal vegetation with coconuts in upland and paddy in the lowland. In view of this difference in vegetation marked differences have been observed in certain properties of the soil which we consider as critical for initiation of laterisation. One such is the content of organic matter. Thus organic matter is higher in forest areas while they are lower in coastal regions.

Mineralogy

The salient finding regarding the primary mineral assemblage, comparative dominance of minerals in the fine sand fraction are given in table 11 and 11.1.

All the three midupland profiles studied at least to a certain depth are composed of soil of secondary origin, derived from the colluvial cum alluvial material derived from the respective upland areas. The midupland laterites are therefore detretal in origin.

Zircon, tourmaline, rutile, hornblende, epidote and chlorite among heavy and quartz and feldspar among the light minerals are known to be generally dominant in the primary mineral assemblage of laterites.

The major primary minerals reported from Indian laterites are quartz, Kaolin, goethite with small amounts of illite and gibbsite. Haematite is also present near the surface (Roonwal and Garlapuri 1982). An unusual feature observed in the study is the high mica content in the profiles of Kulathupuzha and Nedumangad. The fact that they are biotites show the juvenile nature of the soils as under the highly weathering intensities in the Kerala region. Occurrence of biotites in the fine sand mineral assemblage is rarely encountered, contrary to the usual tendency of parsimony in the mineral assemblage, in the profiles of the present study a tendency for a larger number of minerals to occur in the fine sand fraction has been observed. The content of quartz is comparatively high in the midupland profiles in the decreasing order in the profiles of Kulathupuzha $<$ Nedumangad $<$ Varkala. The lower content of easily weatherable minerals in all the locations except Kulathupuzha reveals that the intensity factors of weathering have been very active as to make them nearly extinct. This is in conformity with the earlier finding of Subramonia Iyer (1979).

In some of the studies conducted as comparison of soil properties between forested and deforested area it has been observed that the depletion of organic carbon after deforestation is rapid with appearance of significant signs of laterisation especially the most significant one of induration.

In studying the intensity of weathering an estimate of the relative abundance of resistant minerals like zircon and quartz etc. have been employed in the present investigation. On the basis of the comparative abundance of these minerals the soils are in the increasing order of weathering in the profiles Kulathupuzha midupland > Kulathupuzha upland > Nedumangad midupland > Nedumangad upland > Varkala midupland > Varkala upland.

Iron bearing minerals (Ferruginous) like haematite, limonite, magnetite are appreciably high in the upland profiles. Maghaematite, goethite and haematite content are comparatively more in the upland profiles exhibiting the colluvial nature of their formation. Occurrence of limonite is the characteristic feature of the lower horizons of all the profiles exhibiting comparatively greater hydration in the lower layer and possibly continuously to enable the formation of this mineral.

The ferromagnesium minerals are observed to be present only in traces in all the profiles. Zircon is found to be appreciably high in both upland and midupland profiles at Varkala, intermediary at Nedumangad and rare at Kulathupuzha. The unstable minerals hornblende and feldspars are found commonly in the profiles of the three locations in the decreasing order, Kulathupuzha < Nedumangad and Varkala. The uniformity in the distribution of primary minerals in all the profiles at all locations point to a great similarity in the general nature of the parent material. The quantitative difference especially depletion of unstable minerals and residual accommodation of stable mineral such as Zircon etc, suggest a general higher combination of intensity factors in the coastal region of Varkala which decrease progressively through Nedumangad to Kulathupuzha. This is a significant observation of consequence, which possibly has been influenced by the vegetation also.

MICROMORPHOLOGY

From the Micromorphological angle, certain terms used, though familiar to micromorphologists require definition for comprehension by other Pedologists and Soil Scientists.

Some of the terms of relevance frequently used are given in Appendix.

From the Micromorphological studies of the soil profiles of the laterite soils of these two phisiographic positions at three locations in the state disclosed the pedogenic processes involved in their formation clearly.

The optical properties of soils are largely a function of the mineralogy. The plasmic fabric and the related distribution pattern (RDP) are two of the parameteres which may be used. It may be stressed that different macro-structural elements in the field are expressed as kinds of plasmic fabrics and related distribution pattern (RDP). The normal related distribution pattern (N R D P) is a function of the texture of soil, (Easwaran and Banos, 1976), and hence different NRDP can be observed in the present investigation the specific related distribution pattern (SRDP) as defined by Easwaran and Banos (1976) is due to pedogenitic processes.

At Varkala the upland profile is autochthonous and the argillic horizion continues into the saprolite (Plate 32 to 39), while at Nedumangad the argillic horizion is autochthonous and continues into the saprolite. (Plate 24 to 31). The midupland profiles at Varkala and Nedumangad is with an argillic horizion formed on an oxic material and the oxic material is observed to be redistributed and transported. (Plates 57 to 64 and 49 to 56 respectively). In these profiles they show excellent development of argillans under plain light (Plate 62 and 53). Agglutanic SRDP is clearly seen at Varkala midupland profile (Plates 57 to 64) and Nedumangad profiles (Plates 49 to 56) which indicates that the material prior to clay translocation is oxic. At Nedumangad upland and Varkala midupland, the profile is with a "pale" clay distribution pattern, horizion with argillan are not very deep (Plates 26, 27 and 60 to 62). This is another indication that illuviation is recent and argillic horizion is being formed in an oxic material.

At Varkala upland profile the oxic horizion over lies an argillic horizion. The soil is bisequel. The section of laterite layer (Plate 10) show remnance of cutan, (Plates 62 and 63) while in the underlying argillic horizion good argillans are present. (Plate 64).

Micromorphology clearly revealed that the parent material of Kulathupuzha is sillimanitic gneiss (Plates 20 to 23). In the field the argillic horizion at Kulathupuzha have a friable consistence. Thin section microscopy clearly revealed that it is with an intertextic S.R.D.P. through clay accumulation (Plates 45 to 48 and 21 to 26).

The agglutenic SRDP is more frequent in the Varkala profile (Plates 16 to 23 and 57 to 64), intermediary at Nedumangad (Plates 24 to 39) and rare at Kulathupuzha (Plates 49 to 56 and 40 to 48). The micromorphological observation of this rare SRDP at Kulathupuzha, moderate at Nedumangad and frequent at Varkala clearly reveals the extent of laterisation and hardening of laterites. Between profiles the agglutanic SRDP is the dominant feature with asepic fabric and isotic frequently in the upland profiles of Varkala and Nedumangad is due to more original iron content and ferruginization.

More organic matter, sandy texture, undulating gradient of Kulathupuzha profile sites retarded the iron colloids sufficiently to fix them on the spot (Plate 1 to 4). While at Varkala the least organic matter, higher iron content, flat to gently slopping gradient and loam to clayey texture accelerated the viscous iron colloids sufficiently to fix them on the spot (Plates 9 to 13).

An intermediate situation is observed at Nedumangad profiles (Plates 5 to 8). Between profiles the situation is favourable for ferruginization at upland profiles than the respective midupland profiles in all the locations except Kulathupuzha.

Even though the Varkala and Kulathupuzha profiles are gravelly throughout (Plates 14 and 15), the thin section of the respective layer does not (Plates 16 to 23, 32 to 39 and 40 to 49) reveal any microconcretions or nodules which is an important observation to be noted. At Varkala ferruginous gravels are the lithorelics of original laterite material which are rich in iron (Plates 14 and 15). At Kulathupuzha they are lithorelics of the parent material sillimanite gneiss transported from still higher elevations (Plates 14 and 15).

The presence of runic-quartz and rounded laterite fragments in the midupland profiles at Nedumangad and (Plates 49 to 56) Varkala (Plates 57 to 64) indicates that this is a transported material. The weak plasmic fabric and agglutanic tendency of upland profiles at Varkala (Plates 32 to 39) and Nedumangad (Plates 24 to 31) indicates the oxic nature of material.

Kulathupuzha profiles are sandy textured and there is definite increase in clay with depth (Plates 40 to 56). Due to the texture the structure is weak in lower layers (Plates 19 to 23 and 52 to 56). Some patchy clay skins are observed in the field. Micromorphological study reveals that clay translocation and accumulation is an insignificant process either in past or the current.

At Varkala the profiles are observed with an increase in clay content largely due to accumulation by translocation (Plates 32 to 39 and 57 to 64). The parent material and ustic moisture regime are contributing factors.

The observation of admixing of highly weathered and unweathered material in midupland profiles is clearly indicative of the transported origin (Plates 57 to 64 and 40 to 56) allochthonus formation.

The comparative absence of weatherable minerals at Varkala qualifies the soil as an oxisol. However clay translocation has taken place and the horizion of maximum accumulation of translocated clay is at 78 cms. This implies that clay translocation is recent and taking place in an oxic material (Plates 36 to 39 and 62 to 64).

The kaolinite and sesquioxide material present in all the soil profiles irrespective of the locations have low volume expansion and so the stress orientations are weakly developed. In addition the iron present tends to mask the optical properties. As a result asepic fabrics are frequent and some times tends to be isotic. These are in conformity with findings reported by Bennema <u>et al</u> (1970), Easwaran (1972).

Cutans observed in the thin sections are paler in colour and some times more brownish than the "S-matrix". The pale colours observed in the midupland profile of Varkala and upland profile of Nedumangad may be due to two reasons. First a deferrification process in the surface layer is considered by Lespsch and Bowl (1974), in their investigations on the oxisol ultisol sequence in Brazil as a necessary prerequisite to dissolve the iron, cement and enable the clay to move. Secondly it could be supposed that subsequent to cutan formation water moving through voids could remove iron. The brownish colouration observed in the upper layers of all profiles could be attributed to staining by organic matter. Pure Kaolinite is white. An argillan compared of Kaolinite without sesquioxide coating or admixing with organic matter is also white. The hydromorphic conditions prevailing in the Kulathupuzha and Nedumangad and midupland profiles of Varkala may diffuse the ferrous iron from void wall into the cutan and later perhaps into the 'S-matrix'. Oxidation of iron causes staining of cutans as it is observed in the plinthite layer of midupland profile of Nedumangad and upland profile of Varkala.

The dissolution of iron cement in the upper layers may cause complete bleaching. But some times the cutan may still have reddish colour as is observed in the upland profile of Nedumangad and midupland profile of Varkala. The fact that deferrification may proceed subsequent to cutan formation is observed in the above soil profiles which are macromorphologically almost bleached profiles. At Nedumangad and Varkala in lower layers there are red cutans with an outer layer of yellowish materials.

Intensity of clay illuviation is indicated by volume and thickness of the cutan. According to soil taxonamy (1975) requires 1% by volume of cutan for an argillic horizion. This requirement is not satisfied in the decreasing order in the midupland profile of Varkala upland profile of Nedumangad midupland profile at Nedumangad and upland profile at Varkala ie. in all these profiles there is an argillic horizion in the intermediary stage of formation ie. Strictly speaking this requirement is not fully satisfied in all the profiles investigated. It is an indication that clay translocation is recent and soil is reworked and transported.

A good orientation of cutanic material is generally an indication that the condition favourable for distruction do not prevail in these soils, as is observed in the decreasing order at Kulathupuzha Nedumangad and Varkala.

The midupland profiles irrespective of the locations are developed on transported oxic material. The thin section studies reveal some interesting facts on the above. These midupland soil profiles have fragments of cutan incorporated in the S.Matrix. This suggest that the cutans may be well cemented and during the transport they moved as an entity. Such forms are present comparatively higher as a kind of papules and may be interpreted as relic cutans. Such relic cutans are present comparatively more in midupland profiles than upland profiles irrespective of locations. Pockets of soil material with cutan in a matrix of oxic material observed comparatively at higher intensities in the midupland profiles of Kulathupuzha is a highly localised situation which has not been encounted elsewhere. One of the possibilities is the rolling down and burial of igineous rocky fragments in weathered alluviated lateriate material during the process of erosion. Subsequently insitu weathering of these fragments and cutainsation of such insitu weathered sand by oxic material earlier alluviated has given rise to the plate number 4. It is also evident from the differently coloured and plasmic fabric of cutan cemented entity of the midupland profile that its formation is allochthonus. A reverse pattern is observed in the profiles of Kulathupuzha and upland profiles of Nedumangad and Varkala which indicates that is formation is autochthonus. Except

Kulathupuzha all the profiles investigated posses an argillic horizion in their early stages of formation and all these soils are having a C.E.C. of less than 16 m.eq./100 grm. of soil. The low C.E.C. 16 meg./100 gm of soil is an indication that Kaolinite may be the dominant clay mineral.

Lespsch and Boul (1974) reported that organic acids are involved in reducing the iron causing the cement to break up which is in conformity with the present observation at Kulathupuzha and Nedumangad. A high soil pH and electrolyte if present in the soil clay may accumulate by flocculation. The clay plug and clay papules observed at Nedumangad profiles are indicative of this process.

Flocculation during transport and sedimentation of lateritic material is the most probable cause of the asepic plasmic fabrics observed in the profiles investigated.

The greater the degree of flocculation and the wider the particle size the weaker the degree of orientation as judged by the orientation pattern as observed in the thin section of midupland profile. This is in conformity with the observation of Brewer and Haldae (1956).

The reverse of the above is the recion for sepic plasmic fabric. Vosepic plasmic fabric are the sites of maximum wetting and drying where pressure due to expansion and tension due to shrinkage is maximum; this is exemplified in the silicken sided, plannar shaped voids; which are indisputably due to pressure of swelling and are always accompanied by vosepic fabric observed in the study.

Skelsepic fabric is also due to the result of swelling. Since skeleton grains present a solid surface against which pressure can be exerted.

The isotic plasmic fabric are apparently due to isotropic clay minerals. It is also due to unoriented with regard to their neighbours or to the presence of opaque materials such as organic matter and opaque minerals as is observed in the profiles of Nedumangad and Kulathupuzha.

The reddish brown mass filling the skeleton grains in the plinthite layer is the iron stained Kaolinite with few quartz grains. Increase of cementation observed in the thin section of the plinthite at Varkala upland profile are at advanced stages of "laterite" formation. The pale yellowish brown colour observed in the laterite profiles are mobile iron colloids protected by silica.

Asepic fabric has been observed in the micromorphology of the proiles of Kulathupuzha and Nedumangad. Sepic fabrics is usually considered to be the opposite of asepic fabric and caused by alluviation and consequent stress orientation however, is the one to be expected from profiles in a well known micro watershed such as those from Kulathupuzha and Nedumangad. The exact reasons for the occurrences of aspic instead of a sepic fabric in these profiles is a baffling problem of micromorphology to be answered by examining a large number of slides of profiles from a variety of micro watersheds as compared to interesecting regions of micro watersheds.

The dehydration, concentration and crystallisation which are the aging process, changes the dilute amorphus iron colloids into dense crystalline iron minerals. (Mackenzie 1959) is called "siderization" (sideres - iron) or ferrugin. In the miduplang profiles they may have fragments of this ferruginised solid material. These material form opaque round patches (concretions). However, these do not effervesce with dilute hydrochlorice acid to show that they are carbonates to quantify as siderites. Closelying concretionary particles during pedogenesis may become separated, the intervening voids being filled by iron colloids. The concretions on the other hand as observed in lone cases, come closer especially the angular edges and corners, the in-between space being filled by iron colloids as already indicated. This process of colloidial filling as has been observed in the Varkala and Nedumangad profiles, often leads to an overflow of the collodial iron leading to ferriargillan coatings.

The differential accumulation of Iron containing minerals in the surface horizon of Varkala and the enrichment of Aluminous Colloidal matrix in the subsurface layers needs an explanation from the pedogenic angle. The break down of Kaolinite from surface horizons and differential transport of SiO_2 relative to Iron and Alumina has led to the formation of a plinthitic horizon which by erosion has got exposed and hardened. The vesicular nature of this plinthitic layer is very typical in Kerala in that while the vesicles themselves are mainly constituted by crystallised iron compound the content inside the vesicles are aluminiferous. The torrential rains for nearly six to seven months in the year, and the near continuity of the vesicles to the very regions of the nonvesicular adjacent lower horizon leads to an accelerated lessivage of the aluminiferous material which later gets further leached. These are evident in the plates 10 and 13.

The thin section studies of midupland profiles of all the locations except that of Kulathupuzha revealed that they are formed by the filling and saturating of colluvial laterite deposits with mobile, silica protected iron colloids with little manganese. These iron colloids are supplied laterally from the surrounding ferruginous uplands from whence they flow down the slopes. (Lamotte and Rougerie (1962), Hamilton 1964). This supply might have proceeded until the whole colluvial mass is soaked with it followed by flocculation and crystallization as in the case of upland sites.

The formation of midupland laterite from the upland laterites in the profiles investigated clearly revealed that respective upland profiles are comparatively richer in their iorn content especially at Varkala location. At other locations even though the difference is there, they are narrow because of the little difference in the gradient.

The mineralogy and micrography of all the midupland profiles investigated are not different from that of the upland profile. Thin sections of midupland profiles at Nedumangad and Kulathupuzha on the one hand and the corresponding upland profiles on the other could not be easily distinguished since variations are only on miner points. Genetically the colluvial midupland laterites in view of the colluvial nature itself is known to be younger. Some of them still may contain more stream of active colloidal ferruginous clay. The presence of manganese may be the cause for the dull brown colour of the midupland profiles, when compared to the bright reddish brown colour of upland laterite profiles.

Genesis of upland and midupland laterite soil:

From the present microphological studies evidences indicate normal residual weathering in the upland profiles wherein conditions for laterisation are optimal. They are formed by the above as weathering and drying conditions are optimal. The two optimal conditions in the upland profiles are continuous leaching during the monsoon followed by drying and desication during the ensuring sunny spell. The extent of laterisation is however decreasing in the order Varkala < Nedumangad < and Kulathupuzha. These differences are due to several obvious reasons. Differences in the periods of wetting and drying spells in an year depends on the location. Varkala is in the coast and Kulathupuzha in the western ghats, though all the 3 locations are in the same latitude. The wetting drying spells are markedly influenced by both the vegetation as well as the organic matter accumulated in the soil due to the vegetation. Thus there is a gradient in the intensity of vegertative cover from coastal (Varkala) to Kulathupuzha as well as the increase in the organic matter content of the soil along the same axis.

The midupland laterite profiles are found to be formed by the ferruginization of alluvial deposits. The ferruginizating iron colloids come from the adjoining upland and flow downwards into these deposits. Relic cutans, the relic oxic material possibly alluviated observed in the S-matrix of midupland profiles support the view on the ferruginization of alluvial deposits.

The midupland location at Kulathupuzha with its higher content of organic matter and forest vegetation that its supports, is able to stop the alluviation of eroded material relic or otherwise from the upper region of the slope to a greater extent than is possible in corresponding regions of the midslope either in midlands (Nedumangad) or coastal area (Varkala). This finding is of considerable significance in the need for afforestation to arrest further deterioration of already deteriorated land and ecologically restore the soil. At the same time the findings are crucial in the need to stop deforestation in the western ghats.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSION

Physiographically though Kerala has been divided into coastal, midland and highland regions its meager width is only to the extent of about 75 km. The western ghats considered to be the eroded escarpment of the Deccan plateau by erosive processes is known to have given rise to the agriculturally rich midland region. With laterisation as the overriding soil forming process in almost all the locations in Kerala, the questions to be answered are which is the material undergoing laterisation. Residual or detrital? Further the extent and stage of laterisation as well as the similarities and dissimilarities of the process in various topographical situations have not been examined. Studies on this are often complicated because of even slight differences in the topography. The need for initiating studies on the genesis of laterisation in a location like Kerala thus needs no emphasis. With this objective a study has been undertaken to compare the extent of laterisation in the upland and midupland locations of three distinct physiographic situations represented by Kulathupuzha, Nedumangad and Varkala, all on the same latitude.

Apart from conventional methods of pedological investigations, micromorphological and microscopic methods have been employed to reinforce the observation macromorphologically made.

Some of the salient findings are enlisted below:

1) In all the locations both the upland and midupland profiles are highly gravelly through out.

2) The granulometric composition of upland and midupland profiles irrespective of the locations exhibit almost a similar pattern. The coarse fractions are comparatively more in upland profiles and finer fractions are more in midupland profiles.

3) A laterite layer is significantly absent at Kulathupuzha while it is present both at Nedumangad and Varkala.

4) Consequently fractions between 2 mm and 0.02 mm are less in the upland profiles as compared to the midupland profiles. Thus in the upland profile there is a higher percentage of fraction above 2 mm and below 0.2 mm.

5) Fine sand to coarse sand ratio of surface layer in the upland laterite profiles are of the order 0.36, 0.72 and 0.55 respectively for Kulathupuzha, Nedumangad and Varkala.

6) Silt/clay ratio of the surface layer in the upland profiles are 0.29, 0.52 and 0.75 respectively at Kulathupuzha, Nedumangad and Varkala, while the same ratio for midupland profiles are 0.26, 0.29 and 0.71 respectively.

7) The clay ratio is found to be very nearly the same between the profiles at Kulathupuzha and Nedumangad while at Varkala marked difference is observed between profiles which is an indication that the mid-upland profile is a laterite derived from the soil material brought down from the upper reaches by alluviation.

8) Single value constants obtained for upland profiles are comparatively higher than those of the respective midupland profiles. It increases with depth in all the profiles.

9) Irrespective of locations all the structural indices of laterite soils are influenced by clay, iron and organic matter content.

10) Soils are all acidic in reaction pHw varying between the narrow 4.8 to 5.6 range of in the upland and mid-upland profiles. Irrespective of the location all the profiles have recorded C.E.C. values (4 to 10 meq/100 g of soil).

11) Calcium and Magnesium content follows a definite pattern in the profiles irrespective of locations. They both decrease with depth except in the midupland profiles of Varkala where the magnesium content is found to increase with depth.

12) Total iron content of upland profile is higher than the respective midupland profile in all locations.

13) On the basis of their total iron content the profiles can be placed in the increasing order midupland Kulathupuzha < upland Kulathupzha > Midupland Nedumangad Upland Nedumangad > Upland Varkala and > Midupland Varkala.

14) A rather unusual feature is the high biotite mica content observed in profiles of Kulathupuzha and Nedumangad. Irrespective of the location quartz content is comparatively high in the midupland profiles.

15) On the basis of the comparative abundance of these minerals, the soils are in the increasing order of weathering midupland Kulathupuzha > upland Kulathupuzha midupland Nedumangad < upland Nedumangad < midupland Varkala > and upland Varkala.

16) The micromorphological studies of the midupland profiles of all the locations except that of Kulathupuzha revealed

that they are formed by the filling and saturating of alluvial laterite deposits with mobile silica protected iron colloids with little manganese. These iron colloids are supplied laterially from the surrounding ferrugious uplands from where they flow down the slopes. This supply might have proceeded untill the whole alluvial mass is soaked with it followed by floculation and crystallisation as in the case of upland sites.

17) The present study also revealed that the parent material of Kulathupuzha is sillimanite gneiss while that of Varkala and Nedumangad is gneissic.

18) Asepic fabric has been observed in the micromorphology of the profiles of Kulathupuzha and Nedumangad.

Some of the significant conclusions are follows:-

The vesicular nature of the plinthitic layer observed at Varkala upland is typical of Kerala latterites in that while the vesicles themselves are mainly constituted by crystallised iron compound, the content inside the vesicles are aluminiferous. The torrential rains for nearly six to seven months in the year, and the near continuity of the vesicles to the very regions of the nonvesicular and adjacent lower horizons leads to an accelerated lessivage of the aluminiferous material which later gets further leached.

The present study thus explains the pedological process leading to the accumulation of aluminiferous material at a point of separation of the plinthitic layer to the lower non-plinthitic layer.

In Kulathupuzha region, under its higher content of organic matter and forest vegetation the midupland portion of a slope is able to stop to a greater extent the alluviation of colloidal or relic material than is possible by corresponding region of the midslope either in midlands (Nedumangad) or coastal region (Varkala) with a lower content of organic matter in the soils supporting only man made vegetation. This is of considerable significance in arresting further deterioration of already degraded land and its ecological restoration. The findings further lend support to ecologists in their campaign to stop deforestation along the western ghats.

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APPENDIX

PLATES

1. Kulathupuzha profile site

2. Kulathupuzha surface soil

3. Kulathupuzha upland profile

4. Kulathupuzha midupland profile

5. Nedumangad upland surface soil

6. Nedumangad upland profile

7. Nedumangad midupland surface soil

8. Nedumangad midupland profile

9. Varkala upland surface soil

10. Varkala upland profile

11. Varkala midupland profile site

12. Varkala midupland surface soil

13. Verkala midupland profile

14. Comparative gravel distribution of upland profiles

15. Comparative gravel distribution of midupland profiles

Plate 16 Vosepic plasmic fabric. Note the plasma. Opaque to yellowish brown. Voids are dominantly chambers and channels with almost pure gibbsite.

Kulathupuzha upland 1st layer (0-130m) thin section in plain light Mgf:x63

Plate 17 The plasma is opaque to reddish brown coalased packing of ferriargillan. Vosepic to skele-sepic plasmic fabric. Note the discontinuous inner coating of almost pure gibbsite and Kaolinite.

Kulathupuzha upland 1st layer (0-13 cm) under crossed polarisers Mgf:x63

Plate 18 Plasmic fabric is vosepic to skelsepic and rarely argillasepic. The cutan present is ferran, organ and gibbsan.

Kulathupuzha upland IInd layer (13-32 cm) in plain light Mgf:x63

Plate 19 Vosepic to Skelsepic and rarely argillasepic plasmic fabric. Voids are vughs and vesicles. Skeletons are subangular to subrounded.

Kulathupuzha upland IInd layer (13-32 cm) thin section under crossed polarisers Mgf:x63

Plate 20 Vosepic to argillasepic plasmic fabric. Plasma is dense reddish brown coalased aggregates with ferrans. Voids are vughs and vesicles. Skeletons are dominantly subangular opaque minerals. (Sand sized to fine sand sized quartz).

Kulathupuzha upland IIIrd layer (32-68 cm) thin section in plain light.

Plate 21 Vosepic to argillasepic. Plasma is dense reddish brown. Note the signs of illuviated argillan as argillans with fiant margin. Out of the Skeletons quartz with surface coatings of ferran.

Kulathupuzha upland IIIrd layer (32-68 cm) thin section under crossed polarisers. Mgf:x63

Plate 22 Plasmic fabric is skelsepic to vosepic with chlamydormphic RDP. Skeletons and voids are with discontinuous ferran coatings. Sings of illuviation is also noticed in the argillan.

Kulathupuzha upland IVth layer (68-150 cm) thin section in plain light Mgf:x63

Plate 23 Skelvosepic plasmic fabric. Voids are dominantly planner packing voids with discontinuous ferran coatings. Faint inner and outer margin of the argillan coatings is the sign of illuviation.

Kulathupuzha upland IVth layer (68-150 cm) thin section under crossed polarisers Mgf:x63

Plate 24 Skelsepic to vosepic plasmic fabric. Note vesicles and vughs and high relief opaque skeletons, organ, sesquan. Dense packing (macro aggregates), subangular weathering quarts with sesquan fillings in the fractures.

Nedumangad upland Ist layer (0-36 cm) thin section in plain light Mgf:x63

Plate 25 Skelvosepic plasmic fabric. Note vughs and vesicles, dense packing of sesquan organ in the interangular spaces of skeletons and voids, sub angular runic quartz sand sized subangular weathering quartz with sesquan in fillings in fractures.

Nedumangad upland Ist layer (0-36 cm) thin section under crossed polarisers Mgf:x63

Plate 26 Skelsepic plasmic fabric. Angular to subangular weathering we quartz grains. Note larger grains which are not at extension and have plasma separations associated with their surface.

Nedumangad upland IInd (36-69Ø cm) thin section in plain light

Plate 27 Skelsepic plasmic fabric. Fractured subangular quartz grains with sesquioxide rich plasma separation in the inter angular spaces and in the infillings of the fractures.

Nedumangad upland IInd (36-69 cm) thin section under crossed polariser Mgf:x63

Plate 28 Skelsepic to vosepic plasmic fabric (Dominant Skelsepic). Note the ferriargillans as continuous coating along skeleton grains and voids. Quarts grains are subrounded to rounded. Note the packing of dense ferruginisation patches.

Nedumangad upland IIIrd (69-109 cm) thin section in plain light Mgf:x63

Plate 29 Skelsepic to vosepic plasmic fabric dominantly skelsepic. Note the presence of illuviated argillan around the quartz grains (skeleton). Opaque to brownish red ferruginisation patches covering the major area of the section. Vughs, vesicles and channels are observed.

Nedumangad upland IIIrd (69-109 cm) thin section under-crossed polarisers Mgf:x63.

Plate 30 Vosepic plasmic fabric. Opqque to reddish brown plasma separations without definite pattern of extention in the interangular spaces of voids. Most of the plasma is argillans (ferriargillasepic).

Nedumangad upland IVth layer (109-150 cm) thin section in plain light Mgf:x63

Plate 31 Ferriargillasepic to vosepic plasmic fabric. The voids are coated with ferran and gibbsan (left side).

Nedumangad up IV layer (109-150 cm) thin section under crossed polarisers Mgf:x63

Plate 32 Insepic plasmic fabric. Very loose packing of skeletion grains. Note the presence of runic quartz; ferriargillans, rounded quartz. High relief sesquioxide nodules.

Varkala upland Ist layer (0-13 cm) in plain light Mgf:x63

Plate 33 Insepic plasmic fabric. Note very loose packing of skeletion grains, ferriargillans. Note the presence of rounded quartz with shining margin (runic quartz) in the plasma and in the nodules, vughs, vesicles and channels.

Varkala upland Ist layer (0-13 cm) thin section under crossed polarisers Mgf:x63

Plate 34 Vosepic plasmic fabric. Organic matter rich plasma is present as aggregates incorporating sand sized quartz (sub rounded) and opaque mineral skeletion grains. Note the faint inner margin of plasmafield organic matter aggregates.

Varkala upland IInd layer (13-32 cm) thin section in plain light Mgf:x63

Plate 35 Vosepic plasmic fabric to argillasepic. Note the discontinuous organic matter and sesquioxide coating on skeletion grains and their culsters randomly distributed. Dense packing of plasma. Note the organ, sesquan in fillings in the weathering quartz, vughs and vesicles present.

Varkala upland IInd layer (13-32 cm) thin section under crossed polarisers Mgf:x63

Plate 36 Vosepic plasmic fabric. Dense plasma with sesquan aggregates. High relief opaque skeletion grains. Dominance of Vughs are noticed.

Varkala upland IIIrd layer (32-68 cm) section in plain light Mgf:x63

Plate 37 Vosepic plasmic fabric. Note the ferriargillan coatings along the inner margin of the voids. Vughs are dominant. Ferriargillan (clay papules) well oriented can be observed. Fine sand sized runic quartz is also observed in plasma and in voids.

Varkala upland IIIrd layer (32-68 cm) thin section under crossed polarisers Mgf:x63

Plate 38 Agrillasepic to vosepic plasmic fabric. Note the presence of vughs and vesicles.

Varkala upland IVth layer (68-150 cm) thin section in plain light Mgf:x63

Plate 39 Ferriargillasepic to vosepic plasmic fabric. Silt sized rounded (runic) quartz, to subangular sand sized runic quartz are present. Note the presence of vughs and vesicles with reddish argillans as the boundary.

Varkala upland IVth layer (68-150 cm) under crossed polarisers. Nedumangad upland thin sections.

Plate 40 Argillasepic to voskelsepic plasmic fabric. The skeletion grains are subangular to subrounded weathering quartz and magnetite. Ferriorgan present as subrounded aggregates without any definite extinction pattern. Bigger nodules (sesquioxide) subangular. Vughs and vesicles are present.

Kulathupuzha midupland Ist (0-36 cm) thin section in plain light Mgf:x 63

Plate 41 Argillasepic to voskelsepic plasmic fabric. Notice the nodules with diffused margin and ferriargillan coating. Ferriargillan of the plasma exhibit illuviated features around voids and skeletons.

Kulathupuzha midupland Ist (0-36 cm) thin section under crossed polarisers Mgf:x63

Plate 42 Argillasepic to skelsepic plasmic fabric. Note the presence of more number of sub angular to sub rounded mica, opaque mineral, quartz, Plasma present as opque patches. Small anisotropic domanis are also observable.

Kulathupuzha midupland IInd (36-69 cm) thin section in plain light Mgf:x63

Plate 43 Agrillasepic to Skelsepic plasmic fabric. Note the patches of plasma without striated extension pattern, more number of small anisotropic domains also present.

Kulathupuzha midupland IInd (36-69 cm) thin section under crossed polarisers Mgf:x63

..elsepic to argillasepic plasmic fabric with subangular to subrounded quartz. Plasma is brownish yellow to yellowish brown ferran.

Kulathupuzha midupland IInd layer (69-109 cm) concretion under crossed polarisers Mgf:x63

Plate 45 Vosepic plasmic fabric. Note the presence of a few number of subangular opaque minerals. Note the presence of vughs (bigger sized), channels and chambers with illuviated argillan in the inner margin.

Kulathupuzha midupland IIIrd (69-109 cm) thin section in plain light Mgf:x63

Plate 46 Vosepic plasmic fabric. Note the coalating micro aggregates. Plasmic fabric is vosepic, insepic and in some places isotic. Vughs are present. Note the presence of reddish brown ferriargillans

Kulathupuzha midupland IIIrd (69-109 cm) thin section under crossed polarisers Mgf:x63)

Plate 47 Voskelsepic plasmic fabric. Note the illuviated nature of the ferriargillans, vughs, vesicles and channels are observed. Kaolinite accumulates as oriented skins in the voids. (Lower right)

Kulathupuzha midupland IVth (109-110 cm) thin section in plain light Mgf:x63

Plate 48 Vosepic to argillsepic plasmic fabric. Note the plasma opaque to yellow or brown. Voids are dominantly chambers and channels with almost pure gibsite.

Kulathupuzha midupland IVth (109-150 cm) thin section under crossed polarisers Mgf:x63

Plate 49 Vosepic to skelsepic plasmic fabric. High relief opaque mineral (Magnetite) Ferriorgan along the inner margin of voids. Plasma is dense with ferriorgan. Voids are vughs, vesicles, channels and chambers.

Nedumangad midupland Ist layer (0-23 cm) in plain light Mgf:x63

Plate 50 Vosepic to skelsepic plasmic fabric. Dense ferri-organ forms the plasma. Voids and grains are with ferriorgan cutan. It is also coated with thin coating of gibbsite around skeletons. Domains without definite pattern of extinction is also observed in the plasma.

Nedumangad midupland Ist layer (0-23 cm) crossed polarisers Mgf:x63

Plate 51 Vosepic to skelsepic plasmic fabric. Note the well oriented nature of cutans. The black line runing across the argillan is the extenction line. (left botton). Argillan is with iron stained along the margins of the skeleton and voids.

Nedumangad midupland IInd layer (23-56 cm) thin section in plain light.

Plate 52 Vosepic to skelsepic plasmic fabric. Skeleton gfains are at extension. Bright zone around it is plasma separation with striated extinction pattern, whence is derived the plasmic fabric name skelsepic. Note the iron stained organ around skeleton and voids. Vughs and vesicles are present.

<u>Nedumangad midupland IInd (23-56 cm) thin section under crossed polarisers.</u>

Plate 53 Argillasepic to skelsepic plasmic fabric. Vughs are present. Illuviated ferriargillans are present on the inner margins of vughs and inner margins supporting the skeletion. The argillan bind the grains giving high stability to the soil material.

<u>Nedumangad midupland IIIrd layer (56-87 cm) thin section in plain light.</u>

Plate 54 Argillasepic to skelsepic plasmic fabric. Voids are dominantly vughs with discontinuous rare gibbsan coatings.

<u>Nedumangad midupland IIIrd layer (56-87 cm) thin section under crossed polarisers.</u>

Plate 55 Vosepic to argillasepic fabric. Plasma is reddish brown ferriargillan. Skeletions are subrounded to rounded and are not at extinction. Subangular opaque minerals and presence of opaque weathering biotite mica (right corner)

<u>Nedumangad midupland IVth layer (87-150 cm) thin section in plain light.</u>

Plate 56 Vosepic to argillasepic plasmic fabric. Note the absence of patches of plasma with striated extinction pattern. Small anisotropic domains are also observable.

Nedumangad midupland IVth layer (87-150 cm) thin section under crossed polarisers.

Plate 57 Skel-vospic. Plasma in reddish brown coalised aggregate packing of ferriargillan with plasmafied organic matter. Signs of illuviated argillan in the inside of the voids-vughs and vesicles present. Ferriargillan is densly packed. Related destribution pattern is agglutanic. Plasmic fabric in some places is argillasepic and insepic.

Varkala midupland Ist layer (0-8 cm) in plane light.

Plate 58 Skel-vospic. The plasma opaque to redish brown aggregated to form coalasing microaggregates. Quartz grains present are subangular to subrounded and weathered with ferriargillan coating. Illuviation argillans are few present in larger voids.

Varkala midupland Ist layer (0-8cm) under crossed nicols

Plate 59 Skelsepic plasmic fabric. Plasma few, opaque to brownish red aggregates of ferriargillan. Vughs and vesicles present.

Varkala midupland IInd layer (8-48 cm) in plain light

Plate 60 Skelsepic plasmic plasmic fabric. Skeletons are weathering and weathered. Coarser to sand sized quartz. They are subangular to subrounded. Signs of illuviation argillans are fever, inside bigger voids and along bigger quartz grains.

Varkala midupland IInd layer (8-48 cm) under crossed nicols.

Plate 61 Skelspic plasmic fabric N.R.D.P. is pore-phyros Kelic and in places chlamidomorphic. Plasma few present as opaque to brownishred, iron stained argillan with plasmafied organic matter in the inter angular spaces.

Varkala midupland IIIrd layer (48-72 cm) in plain light

Plate 62 Skelsepic plasma fabric. Vughs and vesicles present. NRDP is granic and in places agglutanic and chlamidomorphic. (dominant chlamidomorphic). Quartz subangular to subrounded, weathered with illuviated ferriargillan coating.

Varkala midupland IIIrd layer (48-72 cm) under crossed nicols.

Plate 63 Plasma is opaque to brownish red ferriargillan aggregates in patches without striated extinction pattern. Plasma is also with silt sized domins. Vughs and vesicles are present.

Varkala midupland IVth Layer (72-150 cm) in plain light.

Plate 64 Plasmic fabric is argillasepic. Vughs and vesicles present with ferriargillan cutan. Runic quartz (rounded to subrounded) are also present. More than 80 percent of the quartz are surface coated with ferriargillan. Few illuviation ferriargillans are present around skeletions.

Varkala midupland IVth layer (12-150 cm) under crossed nicols.

GLOSSARY

Allochtonous. Features not formed in situ c.f. Autochthonous.

Argillans. Cutans composed dominantly of clay minerals.

Argillasepic Fabric. A type of Asepic Plasmic Fabric. The plasma of this fabric consists dominantly of anisotropic clay minerals and exhibit a flecked orientation pattern with recognisable domains.

Asepic Plasmic Fabrics. These fabrics have dominantly anisotropic plasma with anisotropic domains that are unorientated with regard to each other; that is, they have a flecked extinction pattern; There are virtually no plasma separations. There are two types: see Argillasepic Fabric and Silasepic Fabric cf. Scaly fabric.

Autochthonous. Features formed in situ. cf. Allochtonous.

Basic distribution pattern. The distribution pattern of like individuals with regard to each other.

Basic fabric. The fabric of the s-matrix, that is the arrangements and relationships of the plasma, skeleton grains and voids.

Basic orientation pattern. The orientation pattern of like individuals with regard to each other.

Chamber. A relatively large circular or ovid pore with smooth walls and an outlet through channels fissures or planar pores.

Channel. A tubular-shaped pore. cf. Faunal passage, root passage.

Chlamydomorphic fabric: Mineral grains are surrounded by uniform colloidal coatings which may grow together at the points where the grains touch each other. The intergranular spaces are generally empty.

Clay-Humus Complex. Complex formation between humic acids and clay substances, mechanically inseparable, chemically completely divisible only with great difficulty whose nature is little known. Microscopically well-developed clay-humus complexes, in which the humic acids appear as an absorbed dye on the clay substance and easily distinguished from simple mixture of humus and mineral constituents.

Coating. A layer of a substance completely or partly covering a surface. Coatings are composed of a variety of substances separately or in combination. They include clay coatings (clay skins), calcite coatings, gibbsite coatings, gypsum coatings, salt coatings, hematite coatings, organic coatings, whole soil coatings, etc. Coatings may become incorporated into the matrix or be fragmented.

Concretion. 1. A feature caused by local concentrations of compounds that irreversibly cement the soil grains together.

2. A glaebule with a generally concentric fabric about a centre which may be a point, a line or a plane.

3. Concretions are macroscopic amygdali which are more or less rounded and irregular in shape.

4. A segregation of fine material in the s-matrix having a sharp boundary.

Distribution pattern. There are three major groups viz. basic, referred and related distribution patterns.

Ferran. A sesquan (cutan) consisting of iron oxides or hydroxides.

Ferri-argillan. A cutan consisting of a mixture of clay minerals and iron oxides and hydroxides, coloured in shades of yellow, red, green or blue depending on the degree of hydration and oxidation of the iron oxides or hydroxides.

Humus. Clay size organic matter that may exist separately or intimately associated with the clay fraction.

Illuviation Cutans. Formed by movement of cutanic material in solution or suspension and subsequent deposition.

Insepic fabric. A type of Sepic Plasmic Fabric. The plasma separations with striated orientation occur as isolated patches, or islands, within the dominantly flecked plasma, which may have a very weak striated orientation at high magnifications; that is, the domains that exhibit a preferred orientation have a clustered distribution pattern.

Intertextic (related distribution). 1. Bare mineral grains united by intergranular braces or embedded in a porous mass of flocculated or crumbled colloids.

2. The skeleton grains are linked by intergranular braces or are embedded in a porous groundmass.

Isotic Plasmic Fabrics. These fabrics have apparently isotropic plasma; that is, it is indeterminate at even the highest possible magnifications with high light intensities. It may be possible to subdivide isotic fabrics on the basis of the cause of the isotropic characteristics, that is, true isotropy of the minerals and opacity due to iron oxides, organic matter, etc.

Lithorelics. Features derived from the parent rock; usually recognisable by the rock structures and fabric, for example "floater" of parent rock.

Matrix. The fine material (generally 2 um) forming a continuous phase and enclosing coarser material and/or pores.

I-Matrix. The mineral material within this unit of study being simplest (primary) peds, or composing apedal soil materials (in which pedological features occur), or pedological features. It consists of mineral plasma and/or mineral skeleton grains.

O-matrix. The organic material within this unit of study being histons, or simplest (primary) peds, or composing apedal soil materials (in which pedological features occur), or pedological features. Itconsists of tissues and/or organic plasma and/or fungal hyphae, or of organic skeleton grains and/or organic plasma and/or fungal hyphae.

S-matrix. The material (plasma and/or skeleton grains and associated voids) within the simplest (primary) peds, or composing apedal soil material that does not occur as pedological features other than plasma separations; it may be absent in some soil materials, for example, those that consist entirely of pedological features.

Micromorphology. Deals with investigation of soils by methods adapted to the use of small quandities of the material and of the study and interpretations of the details of soil morphology that are not visible to nacked eye.

Nodules. Glaebules with an undifferentiated internal fabric; in this context undifferentiated fabric includes recognisable rock and soil fabric.

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Organan. A cutan composed of a concentration of organic matter.

Papules. Glaebules composed dominantly of clay minerals with continuous and/or lamellar fabric; they have sharp external boundaries. Most commonly they are prolate to equant and somewhat rounded.

Pedological features. Recognizable units within a soil material which are distinguishable from the associated material for any reason, such as origin (deposition as an entity), differences in concentration of some fractions of the plasma, or differences in arrangement of the constituents.

Pedorelics. Features formed by erosion, transport and deposition of nodules of an older soil material or pedological features from it, or by preservation of some part of a previously existing soil horizon within a newly formed horizon.

Plasma. 1. All the material of colloidal size, and relatively soluble material that is not bound up in skeleton grains; it consists of mineral (amorphous and crystalline) and organic material.

2. That part of a soil material which is capable of being or has been moved, reorganised, and/or concentrated by the processes of soil formation. It includes all the material, mineral or organic, of colloidal size and relatively soluble material which is not bound up in the skeleton grains.

Plasma Separation. Features characterised by a significant change in the arrangement of the constituents, rather then a change in the concentration of some fraction of the plasma.

An example of this is the change in orientation of the clay mineral fraction near the surface of slickensides. Plasma separations are not three-dimensional entities, but their internal organization can be described and related to that of the rest of the soil material.

Plasmic fabric. The fabric of the plasma of the s-matrix, that is, the arrangement of the plasma grains and intergranular voids.

Pores. Spaces in the soil filled or partly filled with the soil solution or soil atmosphere. They can be discrete or continuous. With time they may become filled with clay, crystalline material or other substances.

Porphyroskelic. The plasma occurs as a dense ground mass in which skeleton grains are set after the manner of phenocrysts in a porphyritic rock.

Related distribution. Plasma occurs as uniform coatings covering skeleton grains or pedological features.

Related distribution pattern. The distribution pattern of like individuals with regard to the distribution of groups of individuals of a different kind; it can usually be inferred from the referred distribution pattern of the two groups of individuals exhibiting the relationships.

Rubifaction. Reddening of the soil.

Sepic Fabrics. Plasmic fabrics in which patches and/or zones of plasma have striated extinction patterns under crossed polarisers. The following types are recognised:

1. Insepic: isolated patches with a striated extinction pattern.
2. Mosepic: frequent patches.
3. Vosepic: zones associated with voids.
4. Skelsepic: zones associated with grains and/or glabules.
5. Masepic: elongated zones through the plasma.
6. Bimasepic: elongated zones in two directions through the plasma.
7. Omnisepic: all the plasma has a complex striated extinction pattern.
8. Compound fabrics can also occur such as skel-ma-insepic fabric in which several fabric elements are present; in these the weaker elements are named first (skel- in the example). and the stronger elements last (insepic in the example). Speic fabrics can also be compounded with other types. e.g. Skel-massepic undulic fabric.

Sepic Plasmic Fabrics. These fabrics have recognizable anisotropic domains with various patterns of preferred orientation; that is, plasma separations with a striated extinction pattern are present. They can be subdivided on the characteristics of the plasma separation into seven types: Insepic, Mosepic, Vosepic, Skelsepic, Masepic, Lattisepic, Omnisepic fabrics.

Sesquan. A cutan composed of sesquioxides or hydroxides.

Skeleton. Grains of rock forming minerals, rock fragments and bioliths.

Soil Fabric. The arrangement, size, shape and frequency of the individual soil constituents.

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Voids. Entities, which are interconnected with each other either through voids of dissimilar size and shape, through narrow necks, or through intersection with voids of similar size and shape.

Vosepic Fabric. A type of sepic Plasmic Fabric. Part of the plasma has a flecked orientation pattern, but plasma separations with striated orientation occur subcutanically associated with the walls of voids; the striated orientation of the plasma separations is dominantly parallel to the walls of the voids, especially planes.

Vughs. Relatively large voids, other than packing voids, usually irregular and not normally interconnected with other voids of comparable size; at the magnification at which they are recognised they appear as discrete entities.

ABSTRACT

The Western ghats considered to be the eroded escarpment of the Deccan plateau by the erosive process is known to have given rise to the agriculturally rich midupland region of the state. From soil resources point of view the process of laterisation is viewed against the continuous threat of deforestation, bringing more forest lands into agriculture and such other priority areas of resource utilisation and conservation. The results presented deal with a study on the extent of laterisation in the upland and midupland locations of the three distinct physiographic situations represented by Kulathupuzha, Nedumangad and Varkala all on the same latitude. Apart from conventional methods of Pedological investigations, both micromorphological and microscopic methods have been employed to reinforce the macromorphological and physico chemical studies made.

Some of the salient findings are:-

The granulometric composition of upland and midupland profiles irrespective of the locations exhibit almost similar pattern. The coarser fractions are comparatively more in upland profiles and finer fractions are more in midupland profiles.

A laterite layer is significantly absent at Kulathupuzha while it is present at both Nedumangad and Varkala.

Consequently fractions between 2 mm and 0.02 mm are less in the upland profiles as compared to the mid-upland profiles. Thus in the upland profile there is a higher percentage of fraction above 2 mm and below 0.2 mm.

The clay ratio is found to be very nearly the same between the profiles at Kulathupuzha and Nedumangad while at Varkala marked difference is observed between profiles which is an indication that the midupland profile is a laterite derived from the soil material brought down from the upper reaches by alluviation.

Irrespective of locations all the structural indices of laterite soils are influenced by clay, iron and organic matter content.

Total iron content of upland profile is higher than the respective and midupland profile in all locations.

On the basis of their total iron content the profiles can be placed in the increasing order midupland Kulathupuzha upland Kulathupuzha Midupland Nedumangad Upland Nedumangad Upland Varkala and Midupland Varkala.

On the basis of the comparative abundance of these minerals, the soils are in the increasing order of weathering midupland Kulathupuzha upland Kulathupuzha Midupland Nedumangad Upland Nedumangad Midupland Varkala and Upland Varkala.

The vesicular nature of the plinthitic layer observed at Varkala upland is typical of Kerala laterites in that while the vesicles themselves are mainly constituted by crystallised iron compound the content inside the vesicles aluminiferous. The present study thus explains the pedological process leading to the accumulation of aluminiferous material at a point of separation of the plinthitic layer to the lower non-plinthitic layer.

In Kulathupuzha region, under its higher content of organic matter and forest vegetation in the midupland portion of a slop is able to stop to a greater extent the alluviation of colloidal or relic material than is possible by corresponding region of the midslop either in midlands (Nedumangad) or coastal region (Varkala) with a lower content of organic matter in the soils and supporting only man made vegertation. This is of considerable significance in arresting further deterioration of already degraded land and its ecological restoration.