COMPARATIVE MORPHOLOGY AND PHYSICO-CHEMICAL PROPERTIES OF SOME FOREST AND DEFORESTED SOILS OF KERALA

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled " Comparative morphology and physico-chemical properties of some forest and deforested soils of Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship fellowship or other similar title of any other University or Society.

N. SIVADASAN

Vellayani,
November 9, 1989.

CERTIFICATE

Certified that this thesis entitled "Comparative morphology and physico-chemical properties of some forest and deforested soils of Kerala" is a record of research work done independently by Shri N.Sivadasan under my guidance and supervision and that it has not previously formsd the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

Deforestation - temporary or permanent removal of forest cover whether for agricultural or other purposes - has became a matter of serious concern throughout the world. According to the Food and Agricultural Organization (FAO, 1981), 50% of the world's forests have disappeared since 1950. It is estimated that in humid tropics about sixteen million hectares of land are deforested every year. If the present trend of deforestation is allowed to continue, developing countries will loose 40 per cent of their existing forests by 2000 AD. Puri et al (1983) have reported that India has lost 4.04 million km^2 of its forest land between 1951-52 and 1975 -76 as a result of deforestation.

In Kerala, the entire forest area is confined to the eastern half of the State mainly in the rolling plains and mountains of the Western Ghats region. At the beginning of this century, about 44 per cent of the total geographical area was under forest cover. The data from Landsat, 1973 indicate that forest is confined to around 17 per cent of the total geographic area. Though legislation was passed in 1956 reserving the forest as Government property, depletion of forest continues unabated.

According to Chattopadhyay (1985), the rate of deforestation in Trivandrum district was found to be 0.5 per cent per annum between 1973 and 1984 and if that rate of depletion per annum is taken for granted, the State is now left with only 9-10 per cent of natural forest.

The deforestation is caused by the combination of a number of factors. A large area of forest has been felled for plantation crops such as tea, coffee, cardamom, rubber, cashew and economically valuable trees such as teak, eucalyptus etc. After independence different development activities, such as river valley projects, road construction, agricultural expansion aggravated the situation. The mounting pressure of population caused encroachment upon forest land and clearance of forest became a regular practice for settlements, roads, agriculture, collection of fire-wood and other developmental works.

Deforestation brings about a number of environmental problems which have far reaching consequences. Changes in soil properties due to forest denudation are well known. Clear felling removes a large portion of biomass and nutrients from the ecosystem and affects the long term productivity of the soil. Changes in rainfall pattern, increasing rate of soil erosion, changes in groundwater condition and seasonal flow of rivers are other important adverse impacts of deforestation.

Laterite formation occurs mostly in humid tropics both in agricultural as well as in forested regions. Deforestation and subsequent hardening of the soils become a constraint to agricultural development. Continuous denudation of forest along the Western Ghat has also brought about hastening of the process of laterisation. In Kerala, there are different types of forests such as the deciduous, the semi-evergreen, the evergreen and the shola. Deforestation of these different types of forest may bring about laterisation to different extent. Deforestation and monoculture with different economically important tree species and plantation crops such as eucalyptus, acacia, cashew and tea may delay or hasten the process of laterisation to varying extent. The consequent changes in soil properties have not been evaluated in any published works. In view of this, it is felt necessary to study the effect of vegetation, especially monoculture vegetation deliberately planted in recent years in forested areas, on soil properties in comparison with the soils of adjoining virgin soils. The present study with this broad objectives has the following working objectives:-

(1) Collection and compilation of available data on forest vegetation and planted forests/ plantation including that of the geography and geology relating to the sites proposed to be studied.

(2) Delineating the micro and macro morphological differences between soils of forest and plantation sites.

(3) Bringing out the physical, chemical and mineralogical differences among the soils under study.

REVIEW OF LITERATURE

Any soil that has developed under the influence of a forest cover can be considered as a forest soil (Pritchett, 1979). Forest soils are inherently fertile and are frequently younger than the agricultural soils.

Kellogg (1957) defined forest land as one bearing a stand of trees at any stage or stature of growth including seedlings and of species attaining a minimum of 6' average height at maturity or a land from which such a stand has been removed but which has not been put to any other use.

Thomas (1958) emphasized the role of soil in determining the distribution of tropical forests and stated that forests were the cause rather than the effect of fertility in tropical soils.

Devassy (1957) in his report on the working plan for Trivandrum Division, gave a detailed account of the different types of forests found in Trivandrum Forest Division and also the chief species prevailing in each type of forest.

Chandrasekharan (1962) reported that the differences in temperature and precipitation at different altitudes were responsible for the variation in forest vegetation found in Kerala State.

Effect of deforestation

Muller (1887) was of the opinion that clearfelling had no harmful effect. Mc Donald (1955) came to essentially the same conclusion.

Wiedemann (1934) while reviewing the effect of deforestation has concluded that the effect of clear-felling of forests cannot be generalized for all situations. In some cases an unfavourable effect and in others a favourable influence is obtained.

Soil degradation

Clear-felling of natural forests and raising pure crops are detrimental because of the resultant hazards such as soil erosion, depletion of nutrients etc. that may alter the natural equilibrium of the soil (Riquier, 1953).

Evans (1976) stated that without proper soil management practices, clear felling of natural or plantation forests and continuous cropping might result in soil deterioration and the intensity of deterioration would depend on initial soil conditions, topography, climate and management practices.

Greenland (1981) identified important factors responsible for degradation after forest removal as soil erosion, high soil temperatures, imbalance in water uses, decline in organic matter content and nutrient capacity, removal of nutrients in crops and leaching of cations. He summarised that deforestation might result in disturbances of the equillibrium of microclimate, hydrological, chemical and biotic environments. Increase in soil temperature of surface layers as a result of low moisture content and high air temperatures are the direct results of the forest removal.

Delgardo Calvo Flores et al (1985) has supported the above views and has reported that deforested soils have undergone soil and water erosions and physiological and biological degradation.

Physical properties

The important physical properties affected by deforestation are soil particle size distribution, soil structure, bulk density, porespace, water holding capacity and soil temperature.

Particle size distribution

Thomas (1964) observed that 20.3 to 45 per cent gravel in the forest land while 1.1 to 20.7 per cent in the cleared land 2 years after deforestation. According to him sand fraction increased steadily with depth in forest soil whereas it decreased with depth in deforested land. Fine sand fraction in both soils showed a decrease with depth.

Koyamu and Nambiar (1978) studied the changes brought out in surface soil characteristics of a virgin forest land after 11 years of growing plantation crops in the District Agricultural farm, Koothali and they observed an increase in coarse fraction (sand) and a decrease in the finest fraction (clay) in the soils of all fields but with different degrees of variation.

Alexander et al (1981a) observed that sand content decreased and silt and clay increased with depth in deforested soils indicating the downward movement of the latter due to leaching. A study of 3 plantations in comparison with natural forests has shown that sand and silt contents increased with depth in all profiles (Premakumari, 1987).

From a study of the impact of forest clearance in a low land of evergreen forest (Furky, 1987) observed that the fine fraction and soil depth were greatly affected by the clearance. He also found that the proportion of clay diminished on the upper and increased at the foot slope zone whilst soil depth thinned at the submid and increased markedly over the low land.

Structure

The favourable structure of the forest soils is often found to be damaged due to deforestation.Pathak et al (1964) in a study of the physico-chemical properties of soils under cultivation and forest cover showed the forest soils exhibited more aggregation than cultivated ones. Hulton (1976) came to the same conclusion that the mean weight diameter of surface soil aggregates was larger for forested soils than for soils under cultivation. The percentage aggregates > 0.25 mm size were generally higher in the non-forest than in the forest sites.

Mechanical disturbances such as removal of stumps, logging and other activities can damage soil by compaction (Pritchett, 1979).

Wilfred Godwin (1986) while studying the fertility status of soils in South Kerala found that water stable aggregates were higher in the sub surface soils than in the surface soils. He ascribed this to the lesser mechanical disturbances as well as to the binding action of roots and organic matter.

Duchaufour (1987) has revealed that the structure of a moraine forest soil has been degraded under cultivation. He also found that organic matter has a marked effect on the soil structure. Physical entanglement of soil particles by roots, the production of polysaccharide materials (root exudate) from roots and microbial activity and the wetting and drying cycles of the soil are more probable reasons for the observed increase in stability of the soils (Monroe and Kladioko, 1987).

Bulk density, particle density, pore space and water holding capacity

Engler (1919) noticed a lower pore space for agricultural and pastural soils compared to that of the adjacent forest soils.

Pathak et al (1964) found that porosity, water holding capacity and moisture of soils under forest cover were higher than those of the soils under cultivation.

Deforestation and continuous cropping resulted in an increase in bulk density and particle density and a reduction in pore space of the surface soil due to the destruction of soil organic matter (Pritchett, 1979) Gent et al, 1983).

While studying the nutrient recycling under monoculture conditions in tropical forest Prema Kumari (1987) observed higher values for bulk density, particle density and lower values for water holding capacity, pore space and volume expansion in plantation soils compared to natural forest where organic matter content was higher.

Hulton (1976) found that infiltration rates were higher in soils under forest than under agriculture use.

Chemical properties

Riquier (1953) found that removal of forest increased the pH of the soil by checking the subsequent accumulation of organic matter.

Nye and Greenland (1960) reported that acidification on forest removal is aggraved by a decrease in nutrient recycling.

In a comparative study of forest and deforested soilsof Kerala, Thomas (1964) observed that the surface soil of deforested land after 2 years was less acidic due to incorporation of ash in the soil during burning operation connected with the deforestation.

Jose (1968) found increase in pH of the deforested soils as a result of the checking of subsequent accumulation of organic matter. Fuller (1955) attributed this change of pH to the removal of soluble salts by leaching. Koyamu and Nambiar (1978) believed that the lowering of pH might be due to the application of acid forming fertilizers, production of organic acids in the process of decomposition of organic matter and uptake of cations from the soil by the crop.

Mc Coll (1978) in a study of ionic composition of forest soil solution and effects of clear cutting concluded that pH and specific conductance of soil solutions decreased following clear cutting.

Stoin et al (1985) observed that following clear cutting and burning, soil pH was generally higher than in uncut forest soil. The difference in pH was greater within several months and gradually decreased until the end of the second year.

pH when determined in 0.01 M $CaCl_2$ solution recorded a lowering of 0.2 to 2.9 units compared to pH in water (Meena, 1987).

Raveendran Nair (1988) noticed that pH in KCl was always lower than that in water.

Cation Exchange capacity (CEC)

Yadav (1963) reported that the CEC of the forest soils in Chakrata division of U.P. varied from 9.4 to 44 me/100 g of soil and the top A-1 horizon had the highest CEC resulting from an accumulation of humus.

Thomas (1964) observed a higher CEC for the subsoils of cleared land than for natural forest. He attributed this to the greater content of clay and organic matter in those horizons.

Based on a study of the effect of deforestation on the soils of the Anteguera region of Malga, Delgardo Calvo Flores et al (1985) suggested that the removalof forest would result in a reduction of CEC.

Organic matter status

Trimble and Tripp (1949) found that all organic matter disappeared and even after 15 years its content was very low. The practice of slash burning leads to the destruction of organic matter upto 70 per cent in the surface 7.5 cm of soil (Youngberg, 1953).

After clearing a forest in Ghana, organic matter content of the top soil decreased by 57 per cent after 3 years of exposure, whereas undershade the decrease was only 27 per cent (Cunningham, 1963).

According to Thomas (1964) organic carbon has been leached to a greater depth in deforested areas as compared to natural forest.

From a study on the effect of deforestation on organic carbon nitrogen and potassium, Chaly (1965) has reported that organic matter is considerably reduced after denudation. He has also observed a tendency for the level of carbon in the lower layersto increase with increased period of denudation.

Greenland (1981) showed that the rate of decay of organic carbon was significantly increased on forest removal.

Stoin et al (1985) reported that soil organic matter was lower immediately following clear cutting and burning and increased to levels greater than those of uncut forest soils. He also reported that no difference was noticed in the content of organic matter by the end of the second year.

Kawaguchi and Yoda (1986) observed that organic carbon accumulation decreased in the soil remarkably in the first 40 years after clearing and then gradually increased.

Khanna et al (1986) have observed that the higher contents of organic carbon of the soils are correlated with increase in CEC.

Wadsworth et al (1988) have studied the effect of fallow length on organic carbon of some tropical udults and have found that the organic carbon content of surface soils decreased for 10 years following clearing and then gradually increased to approach the original content after 50 years. They have also found that bulk density and organic carbon are statistically significant and negatively correlated.

Nutrient status

Duchafour (1953) pointed out that destruction of forest cover led to heavy leaching and loss of plant nutrients.

Chaly (1965) presented that appreciable amount of potassium was lost by percolation and drainage and soils examined 10-15 years after denudation contained reduced amount of potassium in the surface layer. He concluded that as soil was denuded by deforestation the action of climatic factors like rainfall and temperature became very intensive resulting in accelerated erosion and enhanced leaching.

Jose (1968) noticed a higher percentage of nitrogen and a low C|N ratio in the lower horizons one year after deforestation indicating that decomposition of organic matter, mineralisation and leaching of nitrogen into these layers were at a faster rate immediately after clearing of the forest. He also found that phosphorus accumulated in the second horizon in a deforested soil rather than the surface as in forest. During the prolonged process of thinning and clearfelling of forests, the bases liberated from the decomposing organic matter got quickly and preferentially leached down the profile.

Chandrasekharan Nair (1969) found that the calcium content was highest in the surface soil and it decreased down the profile. He also found that the content of magnesium was invariably proportional to the rainfall.

According to Alifanov (1979) forest soils contain a small amount of available phosphorus and a large amount of exchangeable potassium. The available phosphorus and potassium in the ploughed soil depends upon the fertilizer applied.

Wollum and Gilbert (1975) suggested that nutrients in the forest floor were inversely proportional to the degree of thinning.

Koyamu and Nambiar (1978) noticed a general increase in the phosphorus and magnesium contents in deforested soils 11 years after cultivation. They attributed the increased nutrient availability to the decay of abundant organic matter release and accumulation of nutrients and lesser utilization by the crops.

Adams and Boyle (1980) from a study of the effect of fire on soil nutrients in clear cut and whole harvesting sites concluded that the abundant slash from clearcutting contributed to significant and persistant increase in calcium, magnesium, potassium and nitrogen following a fire, as compared to the whole tree harvest. Five months after a fire, soil calcium, magnesium, potassium and phosphorus at both sites found generally decreased in some cases to the pre-fire levels. The leaching losses of calcium were significantly greater in clear cut site.

Silk worth and Grigal (1982) reported that calcium showed a significant loss associated with whole-tree harvest in the first 5 years after harvest. They also reported that over a 60 years rotation, precipitation and normal weathering would replace nitrogen, phosphorus and potassium lost by product removal and deep leaching, about one half of the magnesium but would not replace calcium. The loss of calcium and magnesium might lead to accelerated soil acidification.

While evaluating the soil fertility at the time of 1 and 5 years after clear cut and whole tree harvest of adjacent oak-aspen forests Adams and Boyle (1980)observed that the surface soil showed an increase in potassium and a decrease in nitrogen concentrations one year following the harvest while similar to original level 5 years after cutting. Calcium and phosphorus levels at both sites five years after cutting were higher than the levels at the time of harvest while potassium and nitrogen were similar to the original levels. Calcium and magnesium concentrations at the clear cut site were 88 and 75 per cent higher than the levels at the whole tree harvest site 5 years after the harvest.

Lear et al (1983) observed that whole tree harvesting of above stump biomass removed more than twice the nitrogen and phosphorus and almost twice the potassium and calcium as conventional harvest of boles only. They also observed that harvesting and/or prescribed burning were the major causes of nitrogen and phosphorus loss. They suggested that harvesting of boles only on rotations of moderate length and leaving the forest floor and logging slash in place would help to minimise the adverse effect of clear-cutting on the nutrient status and thus improve the productivity of the sites from being degraded.

While studying the nutrient dynamics in decomposting lobollypine slash Barber and Van (1984) have reported that woody-logging slash acts as a nutrient sink and may be important in nutrient conservation on cut over areas.

Bruijnzeal and Wiersum (1985) summerised that the whole tree harvesting should not be practised to avoid future shortages of nutrients, especially of phosphorus.

Storage of nutrients nitrogen, phosphorus, potassium, calcium and magnesium in undisturbed forests and minimally disturbed plantation was atleast 10 times greater than in intensively prepared (windrowed) plantations(Morris and Pritchett, 1983).

Available phosphorus levels decreased until there was little difference between the clear-cut and uncut forest soils by the end of the second year. Soil inorganic nitrogen levels were variable but usually were greater on the clear-cut sites than on the uncut sites (Stoin et al, 1985).

Magnesium increases with increase in depth while calcium falls. The low calcium values in B and C horizons result in acid B horizon (Little and Smith, 1986).

C/N ratio

In a comparative study of Indian soils with special reference to C/N ratio, Satyanarayana et al (1946) observed that the general levels of carbon and nitrogen were very low in many soils and the C/N ratio was lying between 5 and 25.

Yadav and Pathak (1963) reported that C/N ratio of forest soils of India varied from 1.5 to 25.4. According to Viro (1974) burning causes marked decrease in C/N ratio. The C/N ratio narrowed from surface horizon to the lowest horizon in the forest as well as in plantation soils (Prema Kumari, 1987).

Iron and aluminium

D' Hoore (1954, 1957) found that iron mobilized to a great degree and to greater depth under tropical grasses than under forest.

Mc Keague and Day (1966) studied the dithionite and oxalate extractable iron and aluminium as an aid in differentiating various classes of soils. According to them, the active iron ratio that is the ratio of oxalate extractable iron ($Fe_{(o)}$) to dithionite extractable iron ($Fe_{(d)}$) is an index of the degree of aging or crystallinity for Free iron oxides.

Schwertmann (1966) illustrated the inhibitory effect of organic compounds in crystallisation of ironoxides and the high $Fe_{(o)}/Fe_{(d)}$ ratios in the surface soils showed presence of high organic matter content in the epipedon. In all the soils studied the values of dithionite extractable iron were considerably higher than the oxalate extractable iron.

Iron is found translocated from the upper to the lower solum along with clay and clay sized particles probably as coatings on layer lattice clays. In well drained soils the iron remained in the clay fraction and is more crystalline as evidenced by the increase of $Fe_{(d)}$ with respect to $Fe_{(o)}$ (Richardson and Hole, 197[illegible]).

Lev-Minzi et al (1971) found that exchangeable aluminium varied from a trace to 370 $\mu g\ g^{-1}$ and was negatively correlated with hydrogen ion concentration. They obtained no correlation between soluble aluminium and iron. Kamprath (1972) while studying the level of aluminium in soil solution found that organic matter formed a very strong complex with aluminium and that as organic matter increased aluminium in the soil solution decreased.

Gallez et al (1975) showed that extractable iron and aluminium oxides were found in soils derived from basalts. In all cases iron oxides existed predominently in crystalline forms.

Thomas (1975) observed that exchangeable aluminium content in the soils decreased with increase in organic matter. Hoyt (1977) concluded that exchangeable aluminium decreased while pH dependent acidity increased with increasing organic matter. Karthikakutty Amma et al (1979) estimated the extractable aluminium in rice soils of Kerala and found that it ranged from 85 to 3700 $\mu g\ g^{-1}$.

Thomas Varghese (1981) while studying the genesis, morphology and physico-chemical characteristics of the laterite soils of Kerala has found that in high land under forest vegetation there is no increase in iron content with depth.

Verma (1982) while comparing pedogenic distribution of aluminium and iron forms in selected soils of Himalayan region identified considerable accumulation of organic matter and amorphous aluminium and iron in B horizon and higher active aluminium and iron ratios in podzols than in the non-podzolic soils.

In a study of the exchangeable aluminium as an index of liming for acid upland soils of Kerala, Meena (1987) showed that at higher values of exchangeable aluminium in the soil the concentration of phosphorus in the top soil decreased due to the strong antagonestic relation between aluminium and phosphorus.

Manganese, Zinc and Copper

Fugitomo and Sherman (1959) estimated copper contents in 87 representative soil samples and found that the content ranged from 16 to 357 $\mu g\ g^{-1}$ with an average value of 124 $\mu g\ g^{-1}$.

Karim and Sedberry (1967) observed a positive significance with total zinc and clay minerals in selected soils on Louisiana.

Ravikumar Praseedom (1970) estimated that the total copper in different soils of Kerala ranged from 5 to 325 ug g and available copper from 0.13 to 4.65 $\mu g\ g^{-1}$. A positive correlation was found between total and available copper, between available copper and organic matter and between available copper and fine fractions of alluvial soils of Kerala. No regularity was noticed in the downward distribution of total and available copper in different soils. He also reported that the total zinc in the soils varied from 3.5 to 100 $\mu g\ g^{-1}$ and available zinc ranged from 0.25 to 8 $\mu g\ g^{-1}$ in the soils of Kerala. He found a positive correlation between total and available zinc and there was no regularity in the downward distribution of total zinc. Available zinc increased steadily with depth.

George Varghese (1971) observed that the contents of zinc and copper decreased with depth in most of the alluvial soils of Kerala. There was no psotive correlation between zinc and organic matter, total nitrogen and potassium. A non-significant positive correlation was noticed between total zinc and the silt and clay content. The total zinc was negatively and significantly correlated to pH. He also observed that the total copper was significantly and positively correlated to organic matter and silt and clay fractions and positively and non-significantly correlated to total nitrogen, phosphorus and potassium. The available zinc and copper contents in the soil were found to decrease with depth.

Bhdhewar and Omanwar (1980) estimated the average DTPA extractable zinc in some Tarai soils under field capacity moisture regime as 1.88 $\mu g\ g^{-1}$ of soil at 10°C which increased significantly to 2.54 and 2.8 $\mu g\ g^{-1}$ of soil at 25°C and 45°C respectively. They concluded that temperature exercised a greater influence on increasing available zinc in soils as compared to moisture.

Mukhopadhyay et al (1983) studied the forms and distribution of manganese in some soils of northern region of West Bengal. He calculated the mean value of total manganese content and ranked the soils in the order Brown forest (794. 4 $\mu g\ g^{-1}$) Teesta and Tarai root hills (704.4 $\mu g\ g^{-1}$) and old alluvial soil (576.6 $\mu g\ g^{-1}$). He observed that the neutral ammonium acetate extracted the least amount of manganese which constituted only 0.2 to 2.2 per cent of the total amount present in the soils. He also observed that on an average the quantity of manganese extracted by the neutral normal ammonium acetate was higher in the surface than in the subsurface.

The total content of zinc for all the soils varied from 12 to 92 $\mu g\ g^{-1}$. Most of the soils had the highest concentration of total zinc in the surface horizon (Chude et al.,1985).

Smirnova and Motuzova (1985) while evaluating the status of copper, zinc and manganese in the soils of sikhote-Aline biosphere preserve have found that zinc concentrations are higher and copper and manganese concentrations are lower than clerks levels in the soil forming rocks and in soils.

They also have found that the contents of the elements-copper, zinc and manganese - extracted by ammonium acetate solution are higher in the upper horizon than in the lower.

Available copper formed a greater portion of its total content than the corresponding values for zinc and not much variation was noticed in the lateral and vertical distribution of copper and zinc in the soils of South Kerala (Wilfred Godwin, 1986).

Influence of vegetation

According to Burger (1926) the quality of a soil is to a great extent a function of the forest stand it supports.

Marbut (1932) studied the relation of soil type and environment. He considers that vegetation was the most important soil forming factor.

Joffe (1936) observed that plants acted directly as a factor of soil formation. He revealed that the type of vegetation-grassland and timber - and the physiological functions of the plants and their composition influenced the constitution of soil profile.

Jenny (1941) recognised vegetation both as a dependent and as an independent variable. He studied the prairie-timber transition zone and emphasized the role of vegetation as an independent variable by illustrating that under equal climatic circumstances a deciduous vegetation stimulated leaching and accelerated soil development more than a prairie vegetation.

Yadav (1968) found that soils under different forest vegetation differed considerably in their physical and chemical characteristics. Wickware and Cowell (1975) reported a correlation between vegetation type and soil.

Wilfred Godwin (1986) has suggested that vegetational cover of the soil seems to superimpose the influence of slope in the retention and redistribution of nutrients as well as different sized soil aggregates and soil particles by altering the amount and velocity of water running through.

Weathering process seems to be quite active in soil under teak followed by eucalyptus cover (Tofey et al. 1986). From a preliminary investigation Alexander (1986) showed that *Acacia albida* was more effective in improving the soils.

Severson et al. (1975) have reported that the major differences in the amount of materials lost from the ecosystem were related to soil type rather than to treatment or vegetation.

While comparing the effect of type of vegetation on erosion on catchment area Avolio et al (1980) found that erosion value was lowest in *Eucalyptus occidentalis* high forest. They suggested that as canopy cover increased erosion was found to be decreased.

Physical properties

Thomas (1964) observed that more clay content was obtained in soils of moist deciduous forests than in other type of forests.

Robinson et al (1966) observed no significant differences in physical properties of soils under indigenous forests and under a sixteen year old tree plantation.

From a study Jose and Koshy (1972) found that constitution of clay was not altered to any marked extent by the removal of natural forests and by maintaining a pure teak vegetation.

Gary and Boggers (1973) showed that bulk density was lower in soils under forests cover than under pine or old field cover.

Rajamannar et al (1979) studied soil samples collected from low and high level lateritic soils under Eucalyptus plantation and found that they were sandy loam in texture. Among the properties of soils under eucalyptus, gravel content was the most and particle density was the least variable factor. Sand silt and clay contents were highly variable where as WHC, pore space, bulk density were only intermedite (Alexander and Thomas, 1985).

Elizebath Chacko (1988) in a study of physico chemical and biological properties of high elevation tea soils of Ponmudi has reported that the texture of tea soils is of uniform clay loam type, indicating the dominance of clay compared to silt and sand fractions. Higher values for bulk density and particle density were noticed in the soils. A higher content of clay (39.98%) in rubber and eucalyptus (37.61%) compared to 27.98% in the natural forest probably indicated a higher degree of weathering and clay formation under the influence of rubber and eucalyptus (Premakumari,1987).

Chemical properties

Doyne (1935) observed that surface soils were generally less acidic than deeper layers because of the stand of species of trees whose foliage contained a high content of bases.

Most of the tea soils of South India show a pH value between 4.5 and 6.0, the figure is higher in some cases (Mann and Gokhale, 1960).

Thomas (1964) observed a higher degree of acidity in soils of moist deciduous forest while Gary and Boggers(1973) studied that pH and exchangeable bases were higher in soils under a native forest cover than under pine or old field cover. Samples collected for low and high level laterite soils under eucalyptus plantation were acidic in reaction (Rajamannar, 1979).

From a study on properties of teak soils Alexander et al (1981 a) concluded that though the teak plantations tended to change pH, organic carbon, CEC and particle size distribution, increase of organic carbon and CEC of the soils during a long rotation of 70 years teak recuperated the soil parameters to its original level. They reported that the pH value of teak soils ranged from 4.2 to 6.6 (extremely acid to neutral) and the pH decreased or remained steady with depth. They also presented data that indicated no marked changes in cation status due to teak cropping.

Alexander et al (1981 b) showed relatively higher levels of organic carbon and CEC in the surface horizon of the profiles under eucalyptus.

Alban (1982) found that soil pH and CEC were highest under pines, which were directly related to the soil calcium content.

In an investigation on 22 spruce fir sites Fernandez and Struchtemeyer (1985) noticed that soil pH increased with depth. They reported that significant correlation existed between exchangeable aluminium and extractable aluminium throughout the profiles.

Tofey et al (1986) studied the effect of forest cover on physico-chemical properties of the soil and found that soil pH was lowered more under eucalyptus plantation than under teak plantation.

Singh et al (1987) studied the chemical properties of soils developed over gneissic rocks under different forest covers and found that CEC was higher under a mixed stand with sal, *Terminalia melanoxylon* and others. Soil pH was higher in A horizon than in the B horizon for all the samples. A lower subsoil pH was noticed under sal. Cation Exchange Capacity of soils cultivated with tea is found to be low (Elizebath Chacko, 1988).

Fertility status

Mann and Gokhale (1960) studied the tea soils of India and reported that the tea soils of South India were generally well supplied with nitrogen that varied about 0.15 per cent to about 0.40 per cent.

While studying the influence of teak plantation on the morphological, physical and chemical properties of deforested soils Jose (1968) found that in natural forest content of calcium and magnesium were higher in the surface soil and decreased with depth. The maximum amount of potassium was present in the second layer. In teak plantation these elements were present more in the lower layers. The surface soils of the natural forests exhibited relatively higher values for C/N ratio and phosphorus content compared to the teak plantation.

Koyamu and Nambiar (1978) observed a reduction in total nitrogen content of soil after a period of 11 years of growing plantation crops except in soils where glyricidia was grown on field bunds and 7.5 to 10 tons of glyricidia leaves per hectare were applied. They also observed a general reduction in potassium and calcium content as well as an increase in phosphorus and magnesium content. A general reduction in organic matter was noticed in top soils except in the field where cocoa was grown as mixed crop with arecanut.

Rajamannar et al (1979) found that the organic carbon content decreased with depth in soils under eucalyptus plantation.

Alban (1982) while studying the effect of different species on soil properties found that organic matter and nitrogen tended to be the lowest under aspen and spruce than under the pines, whereas phosphorus and potassium did not differ with the species. The difference in the soils related to the species were most pronounced in the top 10 cm but only a few occured below 25 cm.

Balagopalan and Jose (1983) observed that the C/N ratio of the soils was little influenced either by depth or by the type of vegetation. The ratio of total nitrogen to available nitrogen increased with increase in depth of soil under teak and mahogany.

In a nutrient balance study in a tropical rain forest in Venezuela, Jordan (1982) has concluded that if the forest is not successional and aggarding, the weathering of parent material doesnot play an important role in the nutrient economy of the ecosystem.

According to Samra et al (1983) vegetation is one of the most important factors affecting the course of soil development under natural wood land ecosystem. They have shown that under natural wood land with deep rooted vegetation, about 4 times more of calcium and magnesium were phytocycled enriching the A horizon. They have also shown that high content of organic carbon throughout the profile is an indication of the dominant role played by vegetation in the genesis of soil.

Compared to natural forests, higher levels of organic carbon occured in teak, eucalyptus and albizzia plantations. Being leguminous, albizzia plantation enhanced nitrogen fixation as well as organic carbon build up in the soil (Balagopalan and Alexander, 1983).

O' Connell and Menage (1983) reported that the order of release of nutrients from decomposing eucalyptus litter was $p < N < Ca < S < Mg < Cl < K < Na$. The rates of decomposition of green leaves differed between soil types in the order of reddish gravels > dark sandy duplex soil > yellow gravels. These differences may be related to the higher nutrient status of the reddish gravel soils.

Adams and Attiwill (1984) have reported that relative abundance of nitrogen in Acacia spp. was a result of nitrogen fixation. They have also found that large amounts of N, Ca, Mg and K are immobilized in acacia biomass, much of which is returned to the soil after canopy closure.

Jha and Pande (1984) concluded that eucalyptus monoculture in natural soil areas causes no damage to soil fertility and is superior to sal monoculture.

Adams and Attiwill (1985) estimated the rates of nitrogen fixation by Acacia dealbeta as 12-32 kg $ha^{-1} yr^{-1}$ which confirms role of acacia as a fast growing pioneer species important in maintaining the nitrogen pool of the forest ecosystem.

Planting of eucalyptus and acacia as monoculture has got very deleterious impact on soil characteristic and fertility (Byju, 1989).

Effect of deforestation on laterisation

History, definition and nomenclature

Buchanan (1807) first gave the name 'laterite' to a weathered material occuring in masses with full of cavities and pores and without any appearance of stratification, overlaying the granitic bed rocks of Malabar. Following this, laterite was found and studied in many places in India and abroad. Kellogg (1949) suggested the term 'latosol' to denote the laterite soils and restricted the word laterite to ferruginous which harden upon exposure and fossil forms of these material. Robinson (1949) coined the terminology 'ferrallitization' for pedogenesis and 'ferrallitisols' for the resultant pedon, while Fitz (1974) named laterite soil as 'Kraznozems' and suggested the possibility of their designation by numerical analysis.

Werner Schellmann (1986) has defined laterite as the product of intense subaerial rock weathering which consists predominently of mineral assemblages of goethite, hematite, aluminium-hydroxides, kaolinite minerals and quartz. USDA (1960, 64, 67 and 75) introduced the term 'Oxisols' to cover the laterite soils in general where the diagnostic characteristic is an oxic subsurface (B) horizon.

Genesis

D'Hoore (1955) showed that laterite can be a consequence of either or both of the following two processes (1) concentration of sesquioxides by removal of silica and bases or (2) concentration of sesquioxide by accumulation from an outside source.

Satyanarayana and Thomas (1961) while studying some profiles of laterite and associated soils in Kerala and South Canara district of Mysore found both gneissic and basaltic rocks beneth laterite.

According to Mary Mc Neil (1964) laterisation occurs most commonly in tropic belt between the latitudes of 30° North and 30° South were high temperatures and heavy rainfall pravils at least during a part of the year.

Laterisation is favoured by fine textured basic rocks derived under humid tropical climate with high temperature and rain fall with intermittent dry period. As a result of this, organic matter gets decomposed rapidly leaving bases as residues, which percolate down on receipt of rain causing alkaline hydrolysis and the silica is leached down the profile leading to accumulation of sesquioxide in the surface of the soil (Patnaik, 1971). The scheme of laterite formation is one where kaolinite clay minerals with absorbed amorphous ferric hydroxide in situ gets transformed to hematite, optionally also to gibbsite and not to goethite but in subordinate quantities (Schmidt Lorenz, 1979).

Moniz et al (1982) suggested that the lateral resilication process is very important in tropical region because it counterbalances the allitization process and explain the occurrence of relatively less weathered clay minerals on lower slope position in the soil scape.

According to Chatelat (1938) laterite soil develops under high precipitation in forest vegetation. Humbert (1948) suggested that laterite formed in a climate that had wet and dry season. The laterite he observed was in an open savannah that was gradually replacing the forest, a common condition where a dry season was prominent. Maignien (1958) reported that laterite was most extensive and strongly expressed at the boundaries of forests and savannah. He also reported that ferruginous laterites might develop on a variety of materials, provided there was a source of iron either in the parent rock or in an adjacent area from where water introduced ferruginous materials. Alexander and Cady (1962) in support of the above views stated that an adequate supply of iron appeared to be essential for laterite formation irrespective of the material in which it was formed. They further noted that the thickness of the laterite crusts was some times related to the iron-richness of the associated rocks.

Sivarajasingham et al (1962) revealed that the laterite could be formed over a variety of parent rocks ranging from basic rocks like basalt and diorite on one side to acid rocks like granite and gneiss on the other side.

In a review of research on laterite, Maignien (1966) stated that most of the contemporary laterite soils developed at mean annual temperature around 25°C and upto an altitude of 2000 m. He reported that laterites were not confined to humid tropics alone but also present in the semi-arid and arid tropics. Laterite soils were mostly seen in tropical environment where annual precipitation was atleast 1200 mm.

Buringh (1970) expressed that the formation of ferrallitic soils was favoured when the soil temperature was 24°C to 27°C throughout the year with mean precipitation of 3000-6000 mm per annum.

Morphology

Harrossowitz (1930) described the four levels of horizons in ascending order from bottom to surface of a characteristic laterite profile developed under a tropical savannah as under:-

a) a fresh zone
b) a zone of primary alteration to Kaolinite
c) a laterite bed proper
d) a surface zone with a ferruginous incrustation and concretions.

Satyanarayana and Thomas (1961) have reported that the colour of laterite soils depends on the content and forms of iron hydroxide and oxides which impart the yellow, pink brown and red colours to the ground matrix and earthy clay. They described the morphology of an idealised in situ laterite profile from Malabar region of Kerala as follows:-

Horizon designation	Characteristic features
A	- Surface soil usually loamy or clayey with iron oxide gravel

BL_1	Crumbly or slag like laterite layer with embedded laterite pebbles of varying sizes
BL_2	Hard, honey-combed or cellular structure having iron oxide skeleton and cavities filled with kaolinitic clay.
BL_3	Vermicular layer, usually quarried having probably equal proportions of iron oxide and kaolinitic material
BL_4	Soft laterite layer (does not retain shape when cut into stones) having greater kaolinitic material.
$BL_{k/s}$	Kaoline layer and/or sand layer
C_1	Weathered rock
C_2	Rock

Gopalaswamy (1969) while presenting the morphological description of 5 laterite profiles in Kerala found no distinct variations in the colour even upto a depth of 250 cm.

Physical properties

According to Kellogg (1949) and Manickom (1977), the intensive weathered laterite soils have very low silt content. Gopalaswamy (1969) and Gowalkar and Datta (1971) reported a decrease in the content of sand fraction with depth in most of the laterite soils examined.

Manickom (1977) in studies on the east coast laterite observed that the values for porosity and water holding capacity registered an increasing trend with depth showing a positive influence of clay and a negative influence of sand fractions with depth.

The bulk density and particle density are uniform in different horizons of laterite soil profiles in Kerala indicating more or less equal weathering for all depths (Gopalaswamy and Nair, 1972).

Chemical properties

Bauer (1898) was the first to recognise chemical characterisation of laterite by pointing out the elevated contents of Fe_2O_3 and Al_2O_3 and the low content of $Si\ O_2$. He also recognised the presence of aluminium hydroxide in a specimen under microscope.

Satyanarayana and Thomas (1962) revealed that the in situ laterite profiles from Angadipuram and Kasargode were acidic in pH (4-5) and extremely low in CEC (2.5 to 7 m.e/100 g of soil) Iron content was high in soil in the surface and intermediate layers. Silica content was found to decrease with depth while alumina content showed a general tendency to increase. The soils were low in bases.

From a study of the chemical composition of five laterite profiles in Kerala Gopalaswamy and Nair (1972) showed that the soils were acidic. The decrease of pH in lower layers was attributed to the advanced decomposition in the clay mass at lower depth. The value of CEC was extremely low with a range of 1.52 to 10.72 me/100 g.

Subramonia Iyer (1979) has observed that laterite soils in general have a low content of available P and K. He also observed that the P content decreased with depth.

According to Thomas Varghese (1981) an organic matter level less than 5 per cent in the surface soil leads to ferrallitization in a conducive laterite environment.

Influence of vegetation

According to Glinka (1927) a forest vegetation was necessary for laterite formation. More detailed studies have shown that while laterite occurs in regions with a rain forest vegetation, well developed laterites are most commonly found under a low forest and that hard superficial laterite is a common feature of the open savannah.

It would appear from the literature that laterite was most extensive in areas of savannah but the laterite forms under forest though its hardening was favoured by lack of forest cover.

Davis (1940) observed that denudation of forest followed by planting of teak resulted either in the formation of laterite or in the exposure of the laterite beds originally present as a result of erosion of the top soil.

Ghani (1951) believed that soils in the evergreen and semi-evergreen forests in East Bengal were in a delicate balance with the opposing forces of laterisation and podsolization.

Maignien (1966) expressed the view that there are reciprocal interaction between vegetation and formation of laterite and incrusted soils.

According to Thomas Varghese (1981) geo-climatic environment, though found to exert a significant role in deciding the extent of ferrallitization, its effect was inhibited by forest canopy and abundance of organic matter in the pedons.

In a comparative study of micromorphological and physico-chemical properties of upland and midland laterite soils of Kerala, Sankarankutty (1986) reported that vegetation and high organic matter content in the mid-upland forests could stop alluviation of eroded material relic or otherwise from the upper region of the slope to a greater extent than was possible in corresponding mid-slope in denuded region.

Hardening and softening of laterite

Rosevear (1942) cited a case where reforestation softened hard laterite significantly in as little as 16 years.

Sivarajasingham (1961) reported that in most cases the chemical, mineralogical and micromorphological differences of soft and hard minerals were not great. A decrease in kaolin was associated with an increase in crystallinity and continuity of goethite which was believed to be the primary cause of the change from soft to hard material.

From a study, Sivarajasingham et al (1962) have observed that maintenance of a moist condition and actively growing vegetation appears to be associated with the process of softening of hard laterite. The process involved the complexing of iron by organic compounds and destroying continuity of crystalline material. They further reported that maintenance of a forest cover, protecting the unconsolidated soil cover and minimising exposure to high temperature and dehydration, prevents hardening of laterite that are still soft.

Walker et al (1969) in a study of titaniferrous latosols in an environment of 30-60" rainfall with altering wet and dry seasons have observed that under normal vegetation these soils consist of friable silt material with very little horizon differentiation, but when the natural vegetation is removed, a surface indurated horizon developed in which bulk density and particle density increased two fold.

Shadfan et al (1985) studied the strength of materials from laterite as well as iron-glaebules and surrounding matrix in Paleudult soil and found a positive linear relationship with dithionite extractable iron and a negative linear relationship with the proportion of oxalate to dithionite iron. They further showed that a suitable crystallization environment allowed the formation of large crystal especially of the goethite type and in large amounts that link together to form a rigid net work and thereby cause the hardening of iron rich materials.

Mineralogy

In a review of research on laterite Maignien (1966) reported that the principal factors determining the nature of alteration of minerals for a given type of rock were essentially drainage condition and ionic content of percolating waters. Conditions of unsaturated and acid pH favoured the formation of Kaoline, deionisation conditions and high precipitation promote crystallisation of aluminium hydroxide in gibbsite.

Manickom (1977) observed that the fine sand mineralogy of majority of east coast laterites in India showed a pattern of mineral distribution containing quartz, iron minerals, zircon, garnet, rutile, anatase, ilmenite and pyroxene.

Chakravarthy et al (1979) reported that mixed weatherable minerals like mica, feldspar, chlorite etc. showed an expression of weathering from parent rocks. He attributed the decrease of resistant and a corresponding increase of weatherable minerals with depth in the pedons in upland to higher rate of surface weathering.

Subramonia Iyer (1979) studied the fine sand fraction of laterite and red soils associations in Kerala and reported that quartz was the dominant light mineral fraction and mica in traces.

Roy and Tan (1981) found that the main minerals of laterite soils in Pulau Langkawi were haematite and ilmenite.

Thomas Varghese (1981) showed that resistant minerals are abundant in coastal and midland laterite soils while highland laterite soils contained a few weatherable minerals

Subbaiah and Manickom (1985) while working on fine sand mineralogy of vertisols of Andhra Pradesh observed that feldspars were the dominant minerals, followed by quartz and mica in the fine sand fraction of six out of seven vertisols. They also observed that the occurrence of early weatherable minerals indicated the low degree of weathering and high nutrient reserves of some profiles.

Samra et al (1985) suggested that difference in soil characteristics developed from the same source may be due to their diverse plant cover. To illustrate this they studied the soils of 4 vegetational sequences of south Khari Forest Divisions in U.P. and showed that under a purestand of _Shorea robusta_, illite was present in relatively high quantity in Udic Ustochrepts and more alteration of illite or neo-synthesis of vermiculite and chlorite seemed to have taken place in comparatively wet soils under _Syzygium cumini_ and _Terminalia alata_.

According to Anand and Gilkes (1987) muscovite is most abundant in laterite developed from granitic parent rock. They estimated 0-17 per cent silt size muscovite in bauxitic laterite of Darling range.

Microorganisms may play a significant role in dissolving (weathering) of feldspars, which is confirmed by the presence of a large number of biogenetic formations on the weathered surfaces of feldspar grains not subjected to sp eluriation (Shoba et al 1987).

While studying the mineralogy of soils from basaltic ash Naidu et al (1987) have observed 3 stages of weathering as follows:-

(i) Weakly weathered soils contain significant amounts of Ca-feldspar in sand fractions.

(ii) Moderately weathered soils contain subordinate Ca-feldspar in sand fractions and

(iii) Strongly weathered soils contain very little Ca-feldspar.

They have concluded that short range order allophanic materials are intermediate weathering products, and that there is a poor or no relationship between precipitation and the amounts of 1:1 minerals and allophonic materials.

Micromorphology

Alexander et al (1956) reported that thin section studies and mineralogical analysis of hard and softened boulders of some laterites revealed an increase in porosity, removal of gibbsite near large pores and cavities, appearance of trace of kaolin, conspicuous arrangements of constituents in the softer specimen. Some parts were highly depleted of iron while other parts were very densely impregnated suggesting that the softening was associated with a decrease in continuity of the impregnating material.

From micromorphological studies Sivarajasingham (1961) found the gridlike net work of oriented materials in the matrix of many hard specimens were composed principally of goethite or hematite.

Eswaran (1972) observed clay migration in oxisols. He recognised that the process was not an active one. Relic features in thin section indicated that the oxisols had undergone through an ultisol stage of soil formation.

In a micromorphological study of indurated laterite concretions Eswaran and Raghu Mohan (1973) noticed that iron formed a vascular net work, the vacuoles being composed of original kaolinite. The net work was formed by closely crystallising goethite which gave the form and hardness of petroplinthite.

Tsuji et al (1975) attributed the higher water holding capacity of oxisols and ultisols to the presence of intra-aggregated void space.

Saad and David (1978) showed that the presence of forest hastened the mobilization of clay and the formation of an argillic horizon. The development of an illuvial horizon was usually associated with encroachment of forest.

Eswaran et al (1979) in a micromorphological study of some highly weathered soil of Peurto Rico observed that physiographic position of pedons would have provided the conditions for weathering intensively but the difference in moisture and temperature regimes was more decisive in that aspect.

Manchanda and Hilwing (1983) observed that the primary birefringient clay cutans and matrans increased with increase in the amount of rainfall. Pedons with 1165 mm rainfall had well developed clay skin to qualify it for argillic horizon and those with 946 and 837 mm rainfall also showed clay cutans but not sufficient to qualify for argillic horizon. The pedon with 426 mm rainfall lacked clay cutans due to low rainfall. They also observed in situ weathered mica grains in all the pedons.

Chartres (1985) in a study of thin sections of hard pan horizons of New South Wales soils recognised a number of different fabric elements which included porphyroskelic zones with amorphous silica in the S. matrix, zones composed almost entirely of amorphous silica, chlamydic zones with clay coatings on skeleton grains and calcarious materials filling the fissures.

Pawluk (1986) studied the characteristic properties of black chernozemic soils after 17 years continuous forest, grass and grain cover as well as summer fallowing. The notable changes in morphological features were associated with fabric rearrangement as reflected in increased compaction and decreased porosity under cropping and fallowing and development of banded fabric and broken down of basic mullgranic fabric units under forest cover.

Chartres (1987) observed fine grained void cutans and grain capping in A and upper B horizons of two podzolic soils in Canberra. They consisted of quartz, mixed clay minerals and traces of feldspar, iron and titanium. He also observed that illuvial clays in the lower B and C horizons consisted of clear reddish orange ferri-argillans.

Righi (1987) reported that deposition of organic mineral compounds in the B horizon would give different kinds of microstructures depending upon the intensity of podzolization process and on the texture and mineralogical composition of the mineral mass of the horizon. In sandy quartzitic materials a strong podzolization process led to a coated microstructure. If a weak podzolization process occurred a microaggregated microstructure of biological origin would form. These two structure occurred in the same horizon. In loamy materials rich in weatherable minerals such as biotite, vermiculite or chlorite, a micronodular structure of physico-chemical origin was formed.

Wadsworth et al (1988) studied the micromorphology of soils under eight different ages of forest regrowth and found that the particle size distribution had a large effect on subsoil micromorphology. Argillic horizon fabric within the finest grained pedon was mostly mosepic with few discrete cutans suggesting that in situ weathering is a dominant clay forming process. Coarser textured pedons had well oriented argillans in the skelvosepic to vomasepic fabric of the argillic horizons.

MATERIALS AND METHODS

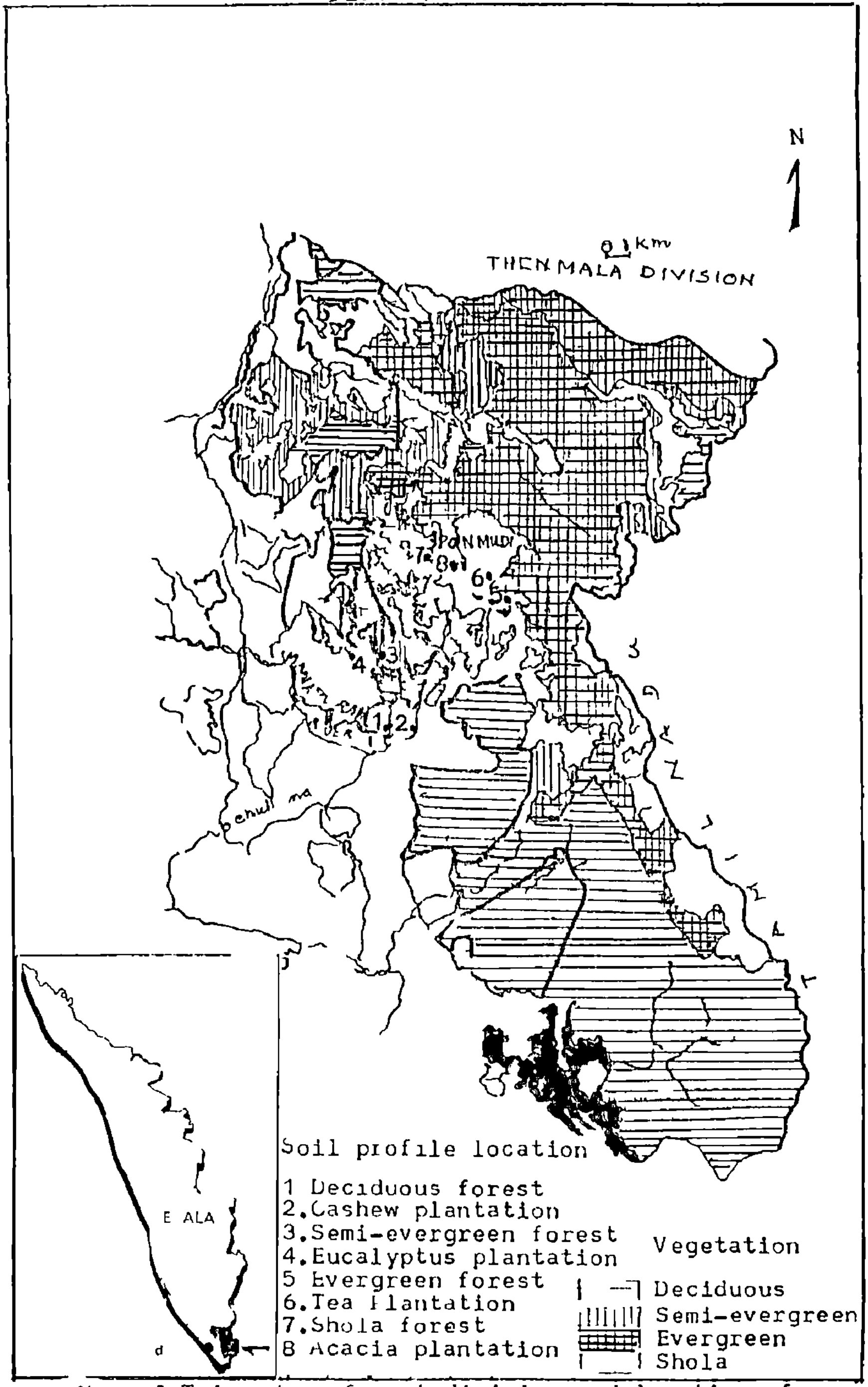
MATERIALS AND METHODS

For the present study entitled "Comparative morphology and Physico-chemical properties of some forest and deforested soils of Kerala" four different forest ecosystems representing deciduous, semi-evergreen, evergreen and shola were selected. From each ecosystem, two profile sites were located one in a virgin forest and the other in an adjacent plantation. The sites located were as follows:

Ecosystem	Profile site
Deciduous	1. Deciduous forest
	2. Cashew plantation
Semi-evergreen	3. Semi-evergreen forest
	4. Eucalyptus plantation
Evergreen	5. Evergreen forest
	6. Tea plantation
Shola	7. Shola forest
	8. Acacia plantation

All the sites were located in Vithura and Thennoor villages of Nedumangadu taluk in Trivandrum district. The entire locations lie within latitude $8^{\circ}41'$ and $8^{\circ}46'$N and longitude $77^{\circ}6'$ and $77^{\circ}8'$E with varying elevations ranging from 230 to 1030 m. The areas enjoy an annual normal rainfall ranging from 2170 to 4190 mm. The map showing the revenue district and selected sites for the study are indicated in Plate 1.

Plate 1



Map of Trivandrum forest division and location of soil profiles

Climatological data of the locations relating to a period of 70 years were obtained. From the quantity of precipitation, seasonality and temperature the 'laterite number' (Karner-Marilaun) for each selected ecosystem was calculated. A value above 50 was considered to be a favourable climatic parameter for laterite formation.

Data relating to vegetation, geography and geology of different sites were also collected and recorded.

Method of collection

At each location pit of size 1.5 x 1.5 x 1.2 to 1.5 m was dug as the diagnostic horizon could be obtained within this depth. Profile features and insitu observations were recorded as per F.A.O. guide lines. After demarcating each horizon, undisturbed samples were taken using a 'Kubiena box'. Then bulk samples were also collected from individual horizons of the eight profile pits for analysis. Core samples were also collected to determine the bulk density and other physical properties.

The colour of the soil on field moisture condition was recorded using a 'Munsell soil colour chart'.

Soil analysis

Preparation of soil samples

A total of 29 sam les were collected, air dried, crushed with wooden mallet, passed through a 2 mm sieve and stored in plastic bottles for chemical analysis.

Gravel content

The gravel content retained in the 2 mm sieve was weighed and expressed as percentage.

Physical properties

Moisture percentage

Ten gram of air dried soil taken in a previously weighed China dish 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.

Mechanical analysis

The mechanical composition of the soil was determined by International pipette method.

Single value constants

Particle density, water holding capacity, volume expansion, pore space etc. were determined by using 'Keen-Raezkowski' box method.

Bulk density

Bulk density was determined by taking core samples as described by Dakshinamoorthy and Gupta (1967).

Aggregate analysis

Aggregate analysis was carried out by wet sieving using Yoder's apparatus as described by Dakshinamurthy and Gupta (1968). Mean weight diameter was used as structural index

Chemical characteristics

Soil reaction

Soil pH was determined in distilled water, potassium chloride (IN), Sodium fluoride (IN) and calcium chloride (0.01M) solutions in the ratio of 1:5 soil solution suspension using a Perkin Elmer pH meter.

Electrical conductivity

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

Organic carbon

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

Total nitrogen

Nitrogen was estimated using the micro kjeldahl method (Jackson, 1973).

Available nitrogen

Available nitrogen was estimated using permanganate titration method by Subbiah and Asija (1956).

Total phosphorus

Total phosphorus was estimated by colorimetry using perchloric nitric acid digest.

Available phosphorus

The phosphorus was estimated by Dickman and Bray's molybdenum blue method (Jackson, 1973).

Total potassium

Total potassium present in the soil was read in a flame photo meter (EEL) using perchloric-nitric acid digest diluted 10 times with distilled water.

Available potassium

Available potassium present in the soil sample was read in a flame photometer using neutral normal ammonium acetate extract (Jackson, 1973).

Cation exchange capacity

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

Total iron

Iron was determined on atomic absorption spectrometer PE 3030, using perchloric nitric acid extract 10 times diluted.

Exchangeable iron

Exchangeable iron present in soil samples was determined colorimetrically by the thiocyanate method in a spectronic 2000 using neutral normal ammonium acetate as extract. The colour was read at 490 m ^{u}.

DTPA - extractable iron

Twenty grams of soil and 40 ml DTPA extractant (0.005M Diethylene triamine penta acetic acid + 0.01 M calcium chloride + 0.1 M Triethanolamine adjusted to pH 7.3 (Lindsay and Norvell, 1969) shaked for 2 hours and filtered through Whatman No.42 filter paper. Content of iron in the extract diluted to 200 times was determined by atomic absorption spectrometry.

Dithionite-extractable iron

Finely ground soil weighing 0.05 g (bulk passing 60 mesh) was placed in a 75 ml test tube, 8 ml of 0.03M trisodium citrate/ 0.125 M sodium bicarbonate solution was added and the suspension was heated in a waterbath at 80°C. Two millilitres of a freshly prepared 20 per cent W/v sodium- dithionite solution, was ad ed, and the suspension was maintained at 80°C, with occasional mixing, for 15 minutes. Two millilitres of saturated sodium chloride were added, mixed and the tube was centrifuged for 10 minutes at 2000 r.p.m. The clear solution was decanted into a 100 ml volumetric flask and extraction repeated. Finally the soil was washed with 8 ml of the tri-sodium citrate/ sodium bicarbonate solution, centrifuged, and the clear washings added to the 100 ml flask.

The combined extractions and washings were made up to 100 ml with distilled water, and the iron in solution was determined by atomic absorption spectrometry.

Oxalate-extractable iron

Finely ground soil weighing 0.2 g (bulk passing 60 mesh) was shaken in the dark for 4 hours in a 15 ml stoppered test tube with 10 ml of 0.2 M acidified (pH 3.0) ammonium oxalate. The suspension was centrifuged at 2000 r.p.m for 10 minutes. An aliquot of the clear solution was taken, diluted 10 times with distilled water and the iron in solution was determined by atomic absorption spectrometry.

Total aluminium

Total aluminium was determined by atomic absorption spectroscopy using perchloric nitric acid extract, diluted 10 times with distilled water.

Exchangeable aluminium

The aluminium present in the soil samples was determined colorimetrically using neutral normal ammonium acetate extract. Pipetted one milli litre of extract into a calibrated test tube, diluted to approximately 20 ml with distilled water. Then two milli litres of thioglycolic acid was added, stoppered and shaked. Ten milli litres aluminon was pipetted into the tube and diluted to exactly 50 ml. The pH adjusted to 4.0 and allowed the colour to develop over night and read in spectronic 2000 at 535 m^{u}

DTPA extractable aluminium

Aluminium was extracted with DTPA extractant used for iron. Content of aluminium in the extract was determined by atomic absorption spectrometry using PE 3030 AAS.

Total manganese

Total manganese was determined by atomic absorption spectrometry using perchloric-nitric acid extract.

Exchangeable manganese

The manganese present in the soil samples was read in atomic absorption spectrometer PE 3030 using neutral normal ammonium acetate extract.

DTPA extractable manganese

Manganese was extracted with DTPA extractant used for iron. Content of manganese in the extract was determined by atomic absorption spectrometry using PE 3030 AAS.

Total Zinc

Total zinc was determined by atomic absorption spectrometry using perchloric nitric acid extract.

Exchangeable zinc

The zinc present in the soil samples was read in atomic absorption spectrometer using neutral normal ammonium acetate.

DTPA extractable zinc

Zinc was extracted with DTPA extractant used for iron. Content of zinc in the extract was determined by atomic absorption spectrometry.

Calcium

Calcium was determined by atomic absorption spectrometry using perchloric-nitric acid extract.

Magnesium

Magnesium was determined by atomic absorption spectrometry using perchloric-nitric acid extract diluted to 100 times.

Water soluble elements

Ten grams of soil was placed in a container and 100 ml of distilled water added. The suspension was shaken for 30 minutes and then filtered using a dry filter paper. Iron was determined by atomic absorption spectrometry using a PE 3030 model AAS.

Aluminium was determined by atomic absorption spectrometry.

Manganese was determined by atomic absorption spectrometry.

Zinc was determined by atomic absorption spectrometry.

Copper was determined by atomic absorption spectrometry.

Mineralogical analysis of fine sand fraction

The fine sand was separated and examined under Petrological microscope. Preliminary treatment and separation of fine sand was conducted during mechanical analysis by the International Pipette method. The dried samples were used for separation of heavy and light mineral fractions using bromoform of specific gravity 2.8 using the method outlined by Carver (1971). The separated fractions were thoroughly washed in alcohol followed by distilled water dried and weighed.

The heavy and light fractions of the fine sand were separated by the method of cone and quartering and mounted on microscope slides using canada balsam. The slides were then examined under a petrological microscope. The minerals were identified on the basis of shape, colour, pleochroism, relief, istropism, anisotropism, angle of extinction and twining. Qaantitative estimation of the minerals was carried out following the line method (Carver, 1971).

Micromorphologicalanalysis

Thin section of soils for micromorphological study was 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 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 overheating. 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 slowly for a while by placing inside an oven maintained at 60°C. After every 2 hours the temperature was raised by 10°C till the temperature reached 110°C. The sample was taken out and cooled in a desiccator for 24 hours.

The sample block was then taken out and ground one surface smooth by hand on a groundglass plate, using successively finer abrasives (first coarse abrasives like carborandum in the order of grades 60, 120, 400 and 600 and finally finer abrasives like alloxite 800 and 1000 grades) until the surface is highly polished. The polished surface was then mounted on a smooth glass slide using lakeside 70 cement.

After mounting, the other side of the chip was ground in the same way moving the chip in opposite direction of the earlier rotation to ensure grinding at all parts of the specimen and at the same rate. Coarse abrasive was used until the sample was relatively thin and then used successively finer abrasives. The sample was frequently examined during the final stages. The final polishing with finest abrasive was done when the chip was ground to a thickness of about 0.03 mm. Washed the section free of abrasive and dried thoroughly.

A small quantity of pre-cooked canada balsam was spreaded over the surface of the thin section and heated on a slide warmer until it was liquid. A cover glass was placed obliquely on one end of the section and lowered gently, squeezing out any air bubbles by pressing lightly on the cover glass. Excess canada balsam was removed with the help of a razer blade after cooling.

The slide was put under a petrological microscope and observations were recorded under plane and polarised (Crossed Nicols) light. Photographs were taken and interpretations made.

Statistical analysis

Data pertaining to the various characteristics were analysed statistically by applying the technique of variance. Simple correlations were also worked out between different characteristics. (Snedecor and Cochran, 1967). The correlation between different soil properties is given in Appendix X(i) and X(ii).

RESULTS

RESULT

Physiographic position of soil profiles

Table 1 presents the geomorphology of the locations of the eight soil profiles studied. The elevation of the locations in the deciduous forest and cashew plantation therein was 230 m while that of the semi-evergreen forest and eucalyptus plantation therein was 200 m above M.S.L. The elevation of the locations of soil profiles in evergreen forest and tea plantation therein as well as of shola forest and acacia plantation therein were at 650, 665, 1030 and 1020 m respectively.

All profiles were located in rolling or undulating topography. Profiles of deciduous forest and cashew plantation were located in the middle slope of mid upland hills while that of semi-evergreen forest and eucalyptus plantation were in the lower slope of upland hills. Evergreen forest and tea plantation profiles were located in the middle slope while profiles of shola forest and acacia plantation were in the upper slopes of highland hills. The slopes of profile sites varied from 8 to 50 per cent. With respect to topography there was similarities between profiles within each ecosystem.

Table 1 Geomorphology of the locations of soil profiles

Sl No	Profile name	Location name	Latitude N La	Longitude E Lo	Physiographic division	Elevation from MSL (m)	Degree of slope	Topography	Parent material
1	Deciduous forest	Anappara in Vithura Village	8°41 - 8°42	77°6 - 77°7	Mid upland	230	18%	Hilly	Granite gneiss
2	Cashew plantation	Anappara in Vithura village	8°41 - 8°42	77°6 - 77°7	Mid upland	230	15%	Hilly	"
3	Semi-evergreen fores	Thalathootha in Vithura Village	8°42 - 8°43	77°6	upland (lower slope)	200	8%	Hilly	
4	Eucalyptus plantation	Thalathootha in Vithura Village	8°42 - 8°43	77°6	Upland (lower slope)	200	10%	Hilly	"
5	Evergreen forest	Thennoor village	8°44 - 8°45	77°7 - 77°8	High land	650	50%	Mountainous	"
6	Tea plantation	Thennoor Village	8°44 - 8°45	7 °7 - 77°8	High land	665	40%	Mountainous	"
7	Shola forest	Thennoor Village	8°45 - 8°46	77°6' - 77°7	High land	1030	12%	Mountainous	"
8	Acacia plantation	Thennoor Village	8°45 - 8°46	77°6 - 77°7	High land	1020	10%	Mountainous	"

Table 2 gives monthly and annual normals of rainfall and rainy days of the locations of profiles. The data related to mean values compiled from 70 years observations showed that in all the locations the rainfall was fairly distributed over a major part of the year. Though the highest rainfall of 4184 mm was recorded at locations 5 to 8, more than 1500 mm of it was received in three months viz. June, July and August. A dry spell was noticed in all locations during the months of January and February when the number of rainy days was less than two per month.

The mean maximum, minimum and annual temperatures of different locations are shown in Table 3. Deciduous forest, cashew plantation, semi-evergreen forest and eucalyptus plantation recorded the mean maximum, mean minimum and mean annual temperatures of 32.6°C, 21.9°C and 27.3°C respectively, while that for evergreen forest, tea plantation, shola forest and acacia plantation were 29.4°C, 19.3°C and 24.4°C respectively.

There was no difference between profiles within each ecosystem as far as temperature and rainfall were concerned.

Table 4 shows relation between annual precipitation seasonality and temperature on expected laterisation of different profile sites. This table is used to find out laterite number (Kerner- Marilaun) whose value above

Table 2 Variation in monthly and annual normals of rainfall and rainy days of the locations of the soil profiles

Sl No	Location	No of years		January	February	March	April	May	June	July	August	September	October	November	December	Annaul
1	Deciduous forest															
2	Cashew plantation	70	a	24 5	21 6	62 7	170 6	233 1	389 3	280 7	175 5	180 4	332 9	231 5	74 5	2177 3
3	Semi-evergreen forest		b	1 7	1 6	6	9	10 1	17 5	15 6	10 9	9 6	13 6	0 6	4 1	107 9
4	Eucalyptus plantation															
5	Evergreen forest															
6	Tea plantation	70	a	25 8	27 1	89 2	179 5	413 6	211 3	722 6	524 2	471 6	663 7	266 5	89	4184 1
7	Shola forest		b	1 6	2 1	4 8	11 6	16 1	22 9	24 1	21 4	17 2	21 3	11 9	4 1	159 1
8	Acacia plantation															

a Rainfall in mm b Rainy days Source Department of Economics & Statistics

Table 3. Annual mean maximum and minimum temperature of the locations of soil profiles

Sl. No.	Profile location	Temperature (°C)		
		Mean maximum	Mean minimum	Mean annual
1	Deciduous forest	32.6	21.9	27.3
2.	Cashew plantation	32.6	21.9	27.3
3.	Semi-evergreen forest	32.6	21.9	27.3
4	Eucalyptus plantation	32.6	21.9	27.3
5.	Evergreen forest	29.4	19.3	24.4
6.	Tea plantation	29.4	19.3	24.4
7.	Shola forest	29.4	19.3	24.4
8	Acacia plantation	29.4	19.3	24.4

Table 4 Relation between annual precipitation, seasonality and temperature on the expected laterisation of different location.

Sl. No.	Location	Annual rain fall mm	Semi-annual rain-fall mm		Mean mini. temp.	Laterite number*
			Wet season	Dry season		
1	Deciduous forest	2177	1590	587	21.9	32.1
2.	Cashew plantation	2177	1590	587	21.9	32.1
3.	Semi-evergreen forest	2177	1590	587	21.9	32.1
4.	Eucalyptus plantation	2177	1590	587	21 9	32.1
5.	Evergreen forest	4184	2860	1324	19.3	36.8
6.	Tea plantation	4184	2860	1324	19.3	36.8
7.	Shola forest	4184	2860	1324	19.3	36.8
8.	Acacia plantation	4184	2860	1324	19.3	36.8

* Laterite number (Kerner-Marilaun) above 50 indicates climatic limits favourable for laterite formation

50 indicates that the climatic limits are favourable for laterite formation. The laterite number (L) is calculated by taking into consideration the values of annual rainfall in mm (R), semiannual rainfall in mm of wet season(s) and of dry season (D) and the mean minimum temperature in degree celsius (tm). Thus $L = R^{-1/4}(S - D)\ tm\ 100^{-1}$. From the derived data it is observed that the locations - deciduous and semi-evergreen forests and their corresponding plantations recorded an 'L' value of 32.1 while locations evergreen and shola forests and their corresponding plantation had a value of 36.8. In all the locations the values recorded were below 50.

Distribution of vegetation

Major portion of the forest fell under the deciduous type. The semi-evergreen type occurred along water coarses and in pockets in the reserves, and evergreen formed only a very small portion confined to the higher slopes. The shola forests were distributed in the rolling downs of the hills. Important species that prevailed in different profile locations were:

(1) Deciduous forest (Plate 2)

It consisted of trees of all ages and species, conspicuously mixed up, thereby affording more than enough light for rank undergrowth to come up. The dominant ones were

Plate 2.

Deciduous forest - a view of the profile location.

Plate 3.

Deciduous forest soil profile

deciduous. The more importent species generally found in the location were:

Tree species: *Tectona grandis*, *Dalbergia latifolia*, *Pterocarpus marsupium*, *Terminalia tomentosa*, *Terminalia paniculata*, *Lagerstroemia lanceolata*, *Vitex altissima*, *Adina cordifolia*, *Albizzia odoratissima*, *Odina wodier* and *Bombax malabaricum*.

Woody climbers: *Spatholobus roxburghi*, *Bauhinia vahli*, *Acacia intsia*

Undergrowth: *Clerodendron infortunatum*, *Helicteres isora* *Lantana camara* and *Uren lobata*

Grass: *Andropogon schaenanthus*

(2) *Cashew plantation*

Cashew (*Anacardium occidentale* L.) planted in the year 1948 after clearing a deciduous forest adjacent to profile location No.1. The treee were full grown with less broken and moderately dense canopy (Plate 4).

(3) *Semi-evergreen forest* (Plate 6)

A closed forest containing a mixture of species belonging to the evergreen and deciduous forests, many of the tallest evergreen trees being absent.

The chief species that prevailed in the top canopy were:

Tree species: *Artocarpus hirsuta*, *Hopea parviflora*, *Adina cordifolia*, *Lagerstroemia lanceolata*, *Lagerstroemia flosreginae*, *Terminalia paniculata*, *Bombax malabaricum*

Plate 4.

Cashew plantation - a view of the profile location.

Plate 5.

Cashew plantation soil profile

Plate 6.

Semi-evergreen forest-a view of the profile location.

Plate 7.

Semi-evergreen forest soil profile

Tetrameles nudiflora, *Holoptelia integrefolia*.

Lower canopy of smaller trees: *Polyalthia fragrans*, *Canarium strictum*, *Cinnamomum* sp. *Aporosa lindleyana* *Xanthophyllum flavascens*; Bamboos and reeds.

Undergrowth : *Clerodendron infortunatum*, *Glycosmis pentaphylla*, *Strobilanthus* sp.

Climbers: *Entada scandens*, *Spatholobus roxburghii*.

4. *Eucalyptus plantation*

The eucalyptus monoculture plantation was established in the year 1983 after clearing a semi-evergreen forest adjacent to profile location No.3. The trees were in the active stage of growth and canopy was not fully covered (Plate 8).

5. *Evergreen forest*

The trees were grown very close together and consisted of entirely evergreen species. The trees were tall and the canopy was unbroken and extremely dense (Plate 10).

Tree species: *Mesua ferrea*, *Calaphyllum tomentosum*, *Palaquim elliptica*, *Gluta travancorica*, *Dysoxylum malabaricum*, *Dipterocarpus bourdelloni*, *Eugenia arnottiana*, *Eugenia jambolana* and *Hopea parviflora*.

Lower Canopy of smaller trees: *Polyalthia fragrans*, *Cinnamomum zeylanicum*, *Hydnocarpus wightiana*, *Evodia roxburghiana*, *Vateria indica*.

Plate 8.

Eucalyptus plantation - a view of the profile location.

Plate 9.

Eucalyptus plantation soil profile

Plate 10

Evergreen forest - a view of the profile location.

Plate 11

Evergreen forest soil profile.

Plate 12

Tea plantation - a view of the profile location.

Plate 13

Tea plantation soil profile

Climbers: *Entada scandens*, *Calycopteris floribunda*, *Diascorea* spp. *Derris* spp.

Undergrowth was very dense and consisted of canes, thorny creepers and large variety of evergreen shrubs.

6. Tea Plantation

The plantation was established in the year 1885 with an area of about 200 hectares. The stand and performance of the tea crop revealed that the plantation was a well maintained one (Plate 12).

7. Shola forest

It consisted of short evergreen and extraordinary variety of species. The trees were grown very close together and canopy was extremely dense (Plate 14). The important species found in the location were:
Exanthophyllum flavescens, *Persea macrantha*, *Aporosa lindleyana*, *Polyalthia fragrans*, *Dimocarpus longum*, *Clerodendron viscosum*, *Poeciloneuron indicum*, *Eugenia jambolana*, *Holigarna arnottiana* *Scheichera oleosa*, *Cinnamomum* sp. and *Elaeocarpus serratus*.
Climbers: *Entada scandens*, *Caesalpinia bonducella* and *Diascorea* spp.

Plate 14

Shola forest - a view of the profile location.

Plate 15

Shola forest soil profile.

8. Acacia plantation (Plate 16)

The acacia plantation was one established in the year 1984 very adjacent to the shola forest (location No.7) The trees had attained a height of about 3 to 5 m and the canopy was not dense and fully covered.

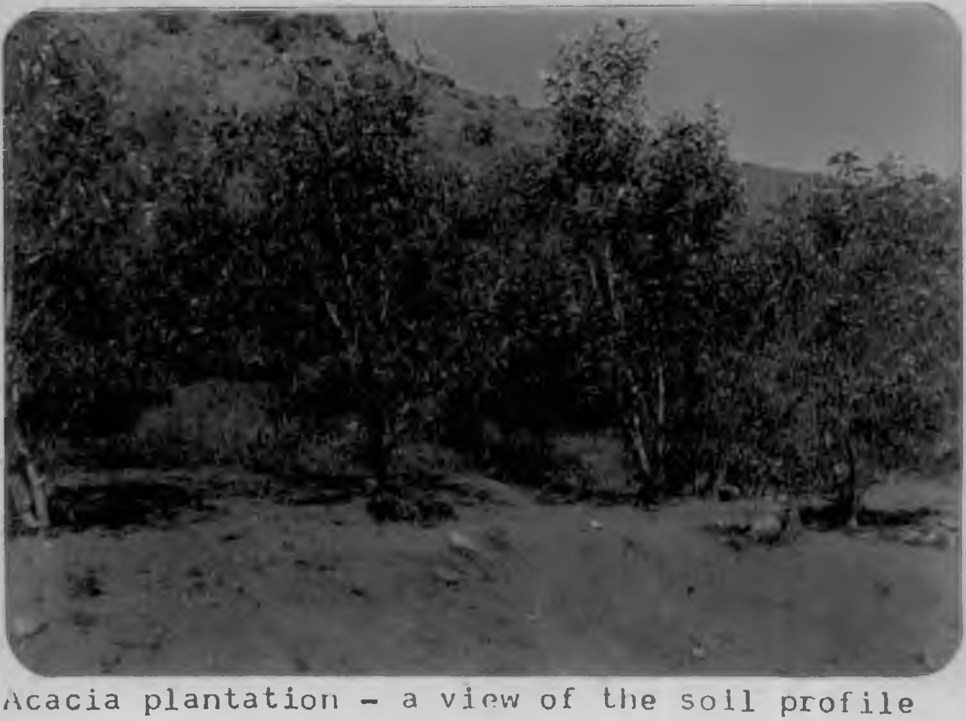
Macromorphology

The comparative macromorphological profile descriptions namely colour, texture, structure, consistency, boundary, presence of roots, permeability, ottling, land use, drainage, depth of groundwater, erosion etc. of the four forests and their corresponding plantations are given in tables 5.1, 5.2, 5.3 and 5.4 as per F.A.O. guideline (1968).

Colour

Deciduous forest had a dark brown surface soil over a yellowish red subsurface soil. Similar observations were recorded for profiles of shola forest, cashew and eucalyptus plantations. The profiles of semi-evergreen forest and tea plantation had subsurface soil with dark red colour while the evergreen forest profile had a very dark grey surface soil and yellow subsurface soil. The acacia plantation profile remained unique with dark reddish brown colour throughout the profile depth.

Plate 16



Acacia plantation - a view of the soil profile

Plate 17.

Acacia plantation soil profile.

Table 1 Macromorphology of soil profiles under deciduous ecosystem

Profile		No 1 DECIDUOUS FOREST	No 2 CASHEW PLANTATION
Location		About 0 5 k o th est o nap a Forest Guard St t it a lage eoum aou Taluk r van rum District	m Northwest of naopara ores rd Station nura ad Neo manoac Talu T andrum District
Series al name		Hapludolls o t r lar association	Hapludolls Kottur Kallar association
a n 1 (		177	2 77
o o hy		adle slope o land ge uno l t c	cdle s ope o m u lan oen u l t ng
e f m m		0	
p		8 e r t n op an li c n x	S e a op g t y c c p
		e c ed	l e
is e		t o g t	t t u
e t w t e n		7	7
iae		ee	e
r e l l		o	o
oc o cr		o	o
no e		tu al o es t o k and m oderately dense canopy	Cultivated mainly cashew e b oken a d moderately dense canopy

o izon de t (cm		(0 – 4) 1	(4 – o) 2	(1o 57) 3	(57– 20) 4	(0 – 19) 1	(19 4 2	(46 20
Colour		D rk b o n 7 5YR /2)	D rk reddish b o n R 2 /2)	Yellowish red (5 R /6)	Yellowish red 5 Y /8	ery dark grey (5 YR /1)	ar o 7 5 YR 2	ello h e 5 Y 5/
Texture		Sandyloam	nd clay loam	Gr ve y y ay lo m	a e ly clay loam	Loam	Cra e o m	C y clay loam
Structure	Size	ne	d u	e um	e	Fine	edium	o r e
	Grade	eak	ode e	o er te	od te t str o	eak	eak	o er te
	Type	Crumb	Crumb	Subangular blocky	Subangular blocky	Granular to crumb	Granular to crumb	Subangular blocky
Consistence	Moist	Friable	ed um i m	Firm	Firm	Friable	Firm	Firm
	Wet	N n sticky N n plas	Slightly st c y S ghtly s c	Sticky l s c	Stick la c	on sticky n plastic	Sl gh v st kv Sl ght l s c	Slightly sticky Slightly plastic

Table 5.1 (contd.)

Profile	Deciduous forest				Cashew plantation		
Horizon depth (cm)	(0 - 4) 1	(4 - 16) 2	(16 - 57) 3	(57 - 120) 4	(0 - 19) 1	(9 - 46) 2	(46 - 20) 3
Porosity size	Fine and medium	Medium	Medium	Medium	Fine to medium	Fine to medium	Fine
Quality	Many	Common	Common	Common	Many	Many	Common
Boundary	Clear smooth	Gradual wavy	Gradual wavy		Clear smooth	Gradual wavy	
Presence of roots (size and quantity)	Fine many medium common	Fine to medium many	Fine few	Very fine Very few	Fine common Medium many	Fine common medium many and coarse few	Fine few
Faunal activity	Earthworm castings				Ants		
Permeability	Rapid	Moderately rapid	Moderate	Moderately slow	Rapid	Moderate	Slowly permeable
Mottling	-	Red (2.5 YR 4/6)	Brownyellow (10 YR 6/8) and reddish yellow (7.5 YR 6/8)	Dark red (2.5 YR 3/6) and reddish yellow (7.5 YR 6/8)	-	-	Red (2.5 YR 4/8) Very pale brown (10 YR 7/4) and Yellowish red (5 YR 5/8)
Pallid zone	-	-	-	Laterite present slightly hard and friable	-		Present moderately soft and friable
Depth of laterite layer (cm)	-	-	-	> 63 cm		-	> 74 cm
Gravel percentage	32.63	38.64	51.95	48.81	38.36	46.95	43.05
Other features							

Table 5 2 Macromorphology of soil profiles under Semi-evergreen ecosystem

Profile	No 3 SEMIEVERGREEN FOREST				No 4 EUCALYPTUS PLANTATION			
Location	Thalathootha 2 5 km N of Anappara Vithura Village Nedumangadu Taluk Trivandrum District				Thalathootha 25 km N of Anappara Vithura Village Nedumangadu Taluk Trivandrum District			
Series and local name	Hapludolls Kottur Kallar association				Hapludolls Kottur Kallar association			
Rainfall (mm)	2177				2177			
Topography	Lower slope of upland hill undulating				Lower slope of upland hill undulating			
Elevation from SL (m)	200				200			
Slope	8% SW Slightly concave along the slope and almost straight across the slope				10% S Slightly convex along and across the slope			
Drainage	Well drained				Well drained			
Moisture in the Profile	Moist				Moist			
Depth of ground water table(m)	4				4			
Evidence of erosion	Sheet and rill				Sheet and rill			
Presence of salt or alkali	No				No			
Rock out crops	No				No			
Land use	Natural forest moderately dense canopy				Cultivated Eucalyptus monoculture canopy not fully covered			
Horizon Depth(cm)	(0 10) 1	(10 - 3 2	(3	4 120 4	(0 1) 1	(11 26) 2	(26 57) 3	(57 130) 4
Colour(field moist)	Very dark brown (10 YR2/2)	Very dark brown (10 YR 2/2)	Dark reddish brown (5 YR 3/2)	Dark red (2 5 YR 3/6)	Dark reddish brown (5 YR 3/3)	Yellowish red (5 YR 4/6)	Yellowish red (5 YR 5/6)	Yellowish red (5 YR 5/8)
Texture	Sandyloam	Sandy loam	Gravelly sandy clay loam	Gravelly sandy clay loam	Gravelly sandy loam	Gravelly sandy clay loam	Gravelly clay loam	Gravelly clay
Structure Size	Coarse	Medium	Medium	Coarse	Coarse	Medium	Medium	Medium
Grade	Weak	Moderate	Moderate	Moderate	Weak	Moderate	Moderate	Moderately strong
Type	Crumb	Subangular blocky	Subangular blocky	Subangular blocky	Crumb	Subangular blocky	Subangular blocky	Subangular blocky
Consistence Moist	Friable	Friable	Firm	Firm	Friable	Firm	Very firm	Very firm
Wet	Non sticky	Slightly sticky	Sticky	Sticky	Non-sticky	Slightly sticky	Sticky	Sticky
	Non-plastic	Slightly plastic	Plastic	Plastic	Non plastic	Slightly plastic	Plastic	Plastic

Table 5 2 (contd)

Profile No		3 Semi-evergreen forest				4 Eucalyptus plantation			
Horizon depth(cm)		(0 -10)	(10 23)	(23 - 42)	(42 - 120)	(0 - 11)	(11 - 26)	(26 - 7)	(57-130)
		1	2	3	4	1	2	3	4
Porosity	Size	Medium	Fine	Very fine	Very fine	Medium	Fine	Very fine	Very fine
	Quantity	Common	Common	Common	Common	Common	Common	Common	Common
Boundary		Clear smooth	Clear smooth	Gradual wavy		Clear wavy	Clear way	Gradual wavy	
Presence of roots (Size and quantity)		Medium many and coarse common	Medium and coarse common	Fine and medium few	Fine few	Medium many	Medium many	Fine common	Very fine few
Faunal activity		Earth worm castings				Termite nests			
Permeability		Rapid permeable	Moderately permeable	slowly permeable	Slowly permeable	Moderately permeable	Slowly permeable	Slowly permeable	Somewhat impermeable
Mottling				Yellowish red (5 YR 4/8) and red(2 5 YR4/8)	Dark red (10 YR 3/6) red(5 YR 4/6) and yellowish brown(10 YR 5/8)			Yellowish red(5 YR 4/8) Red 2 5 YR 5/8) brownish yellow(10YR 6/8) and the least yellow (10YR 7/8)	Yellowish brown(10 YR 5/8) Brownish yellow(10 YR 6/8) and dark reddish brown 5 YR 3/4) are the dominants
Pallid zone					Present friable when moist and hard when dry				Present Slightly hard and friable
Depth of laterite layer(cm)					> 78				> 73
Gravel percentage		28 94	40 5	48 53	49 02	48 68	44 82	47 69	44 06
Other features									Quartz gravel present in abundance

Table 5 3 Macromorphology of soil profiles under evergreen ecosystem

Profile		No 5 EVERGREEN FOREST			No 6 TEA PLANTATION		
Location		Near Merchiston Tea Estate about 6 km away from Kallar on Trivandrum - Ponmudi road, Thennoor Village Nedumangadu Taluk Trivandrum District			Merchiston Tea estate Thennoor Village Nedumangadu Taluk Trivandrum District		
Series and local name		Hapludolls Kottur Kallar association			Hapludolls Kottur Kallar association		
Rainfall (mm)		4184			4184		
Topography		Middle slope of a highland steep hill rolling			Middle slope of a high land steep hill rolling		
Elevation from MSL(m)		650			665		
Slope		50° facing S almost straight along the slope but slightly convex across			40° SE almost straight along the slope but slightly convex across		
Drainage		Well drained			Well drained		
Moisture in the Profile		Moist throughout			Moist through out		
Depth of ground water table (m)		6			6		
Evidence of erosion		Sheet and rill erosion			Sheet and rill		
Presence of salt or alkali		No			No		
Rock out crops		No			No		
Land use		Natural forest dense fully stocked with canopy			Planted with tea		
Horizon depth(cm)		(0-21) 1	(21 - 51) 2	(51 120) 3	(0 - 14) 1	(14 - 30) 2	(30 - 130) 3
Colour(field moist)		Very dark grey (10 YR 3/2)	Reddish brown (5 YR 4/4)	Yellow (10 YR 8/6)	Very dark greyish brown (10 YR 3/2)	Dark brown (10 YR 3/3)	Reddish brown (5 YR 4/4)
Texture		Sandy loam	Gravelly sandy loam	loamy sand	Gravelly sandy clay loam	Gravelly sandy clay loam	Clay loam
Structure	Size	Medium	Medium	Medium	Medium	Medium	Medium
	Grade	Weak	Moderate	Weak	Weak	Moderate	Strong
	Type	Crumb	Subangular blocky	Subangular blocky	Crumb	Subangular blocky	Subangular blocky
Consistence	Moist	Friable	Firm	Friable	Friable	Firm	Very firm
	Wet	Non-sticky	Slightly sticky	Non-sticky	Slightly sticky	Sticky	Sticky
		Non-plastic	Slightly plastic	Non-plastic	Slightly plastic	Plastic	Plastic

(contd)

Table 5 3 (contd)

Profile	No 5 Evergreen forest			No 6 Tea plantation		
Horizon deputh (cm)	1	2	3	1	2	3
Porosity Size	Medium	Medium	Medium	Medium	Medium	Medium
Quantity	Common	Common	Common	Common	Common	Common
Boundary	Gradual wavy	Abrupt smooth		Gradual smooth	Abrupt smooth	
Presence of roots (size & quantity)	Coarse and medium many	Coarse and medium many	Fine few	Fine many medium common	Medium and fine common	Medium and fine common
Faunal activity	-				-	
Permeability	Moderately rapid	Moderately rapid	Moderate	Moderately rapid	Moderate	Moderate
Mottling	Few brownish yellow(10YR6/6) yellowish brown (10 YR 5/8) reddish yellow (5 YR 6/8) and multicoloured stones and cobbles	Yellowish brown (10 YR 6/4) Very pale brown (10 YR 8/4) Yellowish brown (10 YR 5/8) and multicoloured stones and cobbles	Very pale brown (10 YR 8/9) Yellowish red (5 YR 4/8) light grey (5 YR 7/1) are the dominants	Absent	Red(2 5 YR 4/8) Light red (2 5 YR 6/8) and Reddish yellow (5 YR 7/8)	Mainly red(5YR 4/8) Yellowish red (5 YR 4/8) and few multicoloured mottles present
Pallid zone	-	-	Present soft and friable in the initial stages of laterisation	-		Present slightly hard and friable
Depth of the laterite layers(cm)			> 69			> 100
Gravel percentage	25 62	52 75	41 43	50 48	44 95	38 92
Other features	-	-	-	-	-	-

Table 5 4 Macromorphology of soil profiles under Shola ecosystem

Profile	No 7 SHOLA FOREST					No 8 ACACIA PLANTATION		
Location	Ponmudi top 50 m behind the Deer park Thennoor village Nedumangad Taluk Trivandrum District					Ponmudi top 500 m away from the Deer Park by the side of Ponmudi-Trivandrum Road Thennoor Village Nedumangadu Taluk Trivandrum District		
Series and local name	Hapludolls Kottur Kallar association					Hapludolls Kottur Kallar association		
Rainfall(mm)	4184					4184		
Topography	Upper slope of a gently sloping high land hill undulating					Upper slope of a gently sloping high land hill undulating		
Elevation from MSL(m	1030					1020		
Slope	12% S slightly convex across and along the slope					10% S slightly concave along and convex across the slope		
Drainage	Well drained					Well drained		
Moisture in the profile	Moist throughout					Subsoil moist		
Depth of ground water table (m)	4					4		
Evidence of erosion	Sheet and rill					Sheet and gully		
Presence of salt/alkali	No					No		
Rock out crops	Hard laterite out crops plently in the surroundings but scarce at the profile site					Hard laterite outcrops plently in the surroundings		
Land use	Nature forest dense fully stocked with canopy					Cultivated Acacia plantation canopy no dense and fully covered		
Horizon Depth (cm)	(0 12) 1	(12 27) 2	(27 56) 3	(56 67) 4	(67 - 140+) 5	(0-24) 1	(24-79) 2	(79 120+) 3
Colour (field moist)	Dark reddish brown(5YR 3/2)	Reddish brown (5YR 4/4)	Reddish brown (5 YR 4/3)	Yellowish red (5 YR 5/8)	Red(2 5YR 5/8) and yellowish red (5 YR 5/8)	Dark reddish brown(5YR 3/2)	Dark reddish brown(5YR 3/3)	Dark reddish brown(5YR 3/4)
Texture	Sandy loam	Sandyloam	Gravelly sandyloam	Gravelly sandy clay loam	Gravelly sandy clay loam	Gravelly sandy loam	Sandy loam	Sandy loam
Structure								
Size	Medium	Fine	Medium	Medium	Fine	Coarse	Medium	Medium
Grade	Weak	Weak	Moderate	Moderate	Moderate	Weak	Moderate	Moderate
Type	Crumb	Crumb	Subangular blocky	Subangular blocky	Subangular blocky	Crumb	Subangular blocky	Subangular blocky
Consistence								
Moist	Friable	Friable	Firm	Firm	Firm	Friable	Firm	Firm
Wet	Non plastic	Slightly plastic	Slightly plastic	Plastic	Plastic	Non plastic	Slightly plastic	Slightly plastic
	Non sticky	Slightly sticky	Slightly sticky	Sticky	Sticky	Non-sticky	Slightly sticky	Slightly sticky

Table 5.4 (contd.)

Profile	No. 7 Shola forest					No. 8 Acacia plantation		
Horizon depth (cm)	(0-12) 1	(12-27) 2	(27-56) 3	(56-67) 4	(67-140+) 5	(0-24) 1	(24-79) 2	(79-120+) 3
Porosity size	Coarse	Medium	Fine	Fine	Fine	Coarse	Medium	Fine
Quantity	Common	Common	Common	Common	Common	Common	Common	Common
Boundary	Gradual smooth	Gradual wavy	Gradual wavy	Gradual wavy		Abrupt wavy	Gradual smooth	
Presence of roots (size and quantity)	Coarse and medium many	Medium many	Medium and fine common	Medium few	Fine few	Medium to fine many	Medium to fine common	Medium to coarse few
Faunal activity	Ant					No distinct		
Permeability	Moderately rapid	Moderately rapid	Moderate	Slowly permeable	Slowly permeable	Moderately rapid	Moderate	Slowly permeable
Mottling		-	Brownish yellow (10 YR 6/6) and very pale brown (10 YR 7/4)	Yellowish red (5 YR 5/8) and light grey (7.5 YR 7/0)			Pale grey	Pale grey
Pallid zone	-		-		Soft and friable			
Depth of laterite layer (cm)		-		-	> 73	-		-
Gravel percentage	20.00	7.46	49.52	51.38	28.83	31.47	29.21	24.73
Other features			Relic feature present. More quartz and gravel noticed	Micaceous, more pressure faces, faintly discontinuous clay skin present	Leptynite rocky pieces present. Very faintly discontinous clay skin present		Few stones and cobbles partially weathered present	Few boulders and cobbles partially weathered present

The subsurface soils were found to be darker as compared to the surface soils. The intensity of hue varied from 10 YR to 2.5 YR showing a decrease in the value with increase in depth, except in evergreen forest profile where the bottom horizon had a light hue of 10 YR.

There was no marked difference in soil colour between deciduous forest and its corresponding plantation (cashew), but some differences existed between forest and corresponding plantation profiles in semi-evergreen, evergreen and shola ecosystems.

Texture

In all the forest profiles, the subsoils were gravelly textured. The soil texture lied between sandy loam to gravelly clay loam in forest profiles whereas in plantation profiles it was from gravelly sandy loam to gravelly clay (Tables 5.1, 5.2, 5.3 and 5.4).

Structure

The depth-wise variation in soil structure in forest profiles was from weak medium to fine crumb to medium to coarse subangular blocky. The same pattern of structure with no marked difference was observed in plantation profiles with slight variation in grade and size (Tables 5.1, 5.2, 5.3 and 5.4).

Consistency

All soil profiles, except that of evergreen, behaved in a like manner with respect to consistency. The surface soils remained friable, non-sticky and non-plastic while the sub-surface soils were firm, sticky and plastic or intermediate. The lower layer of evergreen forest profile on the other hand remained non-sticky and non-plastic with depth (Tables 5.1, 5.2, 5.3 and 5.4).

Boundaries

The horizon boundaries of deciduous and semi-evergreen forests and their corresponding plantations were clear smooth in top and gradual wavy at bottom. In the case of evergreen forest, the boundary was gradual wavy to abrupt wavy while in shola forest it was gradual smooth to gradual wavy. In the tea plantation, the boundary was gradual smooth to abrupt wavy and in acacia plantation it was abrupt wavy to gradual smooth.

While comparing profiles within each ecosystem, there was marked difference in horizon boundaries between forest and plantation profiles in evergreen and shola eco-systems, whereas such difference was noticed in deciduous and semi-evergreen ecosystems (Tables 5.1, 5.2, 5.3 and 5.4).

Presence of roots

The activity of coarse and medium roots was more abundant in the surface soil as compared to the subsurface soil. In acacia plantation, few medium and coarse roots were noticed in the lowest horizon (Table 5.4).

Between profiles within each ecosystem there was not much difference in the extent of root activity.

Permeability

In all soil profiles permeability was rapid or modertately rapid in the upper horizons and slowly permeable in the lower horizons. In evergreen forest, permeability was moderate in the lower layer, while it was almost impermeable in the case of eucalyptus plantation (Tables 5.1, 5.2, 5.3 & 5.4).

Comparing the profiles in each ecosystem, there was not much difference in permeability except in the case of semi-evergreen ecosystem where marked difference was noticed in the lowest layer of the semi-evergreen forest profile and its corresponding plantation (eucalyptus) profile.

Mottling

Mottling was rarely observed in surface horizon in all profiles except in the case of evergreen forest where multicoloured- brownish yellow (10 YR 6/6),Yellowish brown

(10 YR 5/8) and reddish yellow (5 YR 6/6)-stones and cobbles were noticed as mottles. In all lower horizons multicoloured mottles- brownish yellow, reddish yellow, yellowish red, dark red, yellowish brown red etc. were invariably noticed in all profiles except that of acacia plantation where grey mottles alone were observed in 2nd and 3rd horizons (Table 5.1, 5.2, 5.3 and 5.4). In the case of deciduous forest profile few small red (2.5 YR 4/6) mottles alone were noticed (Table 5.1).

No similarity was observed in the case of mottling between profiles in each ecosystem.

Land use

The four forest profiles were located in virgin forests coming under different ecosystems namely deciduous, semi-evergreen, evergreen and shola, whereas plantation profiles were located in nearby land, originally forest, but cleared and cultivated with plantation crops such as cashew, eucalyptus, tea and acacia respectively.

Drainage

All profile sites were situated in well drained locations with no stagnant water even after heavy rains. There was similarity with respect to drainage in all the profiles.

Depth of ground water

Depth of ground water varied from 4 to 7 m. In locations coming under semi-evergreen and shola ecosystems, it was 4 m deep where as in locations under deciduous and evergreen ecosystems it was 7 and 6 m respectively at the time of observation (Tables 5.1, 5.2, 5.3 and 5.4).

Between profiles within each ecosystem there was no significant difference in ground water table.

Evidence of erosion

In deciduous forest and acacia plantation profile sites erosion was slightly severe resulting in the formation of gullies. In all other profile sites only sheet and rill erosions were noticed (Tables 5.1, 5.2, 5.3 and 5.4).

Laterite horizon

Laterite horizon was generally soft and friable in the forest profiles where it was present at tho bottom horizon after a depth of 40 cm (approx.). In the plantation profiles except acacia, it was present at the bottom horizon. It was soft and friable in cashew, semi-evergreen and shola soils (Table 5.1, 5.2 and 5.4) while slightly hard and friable in eucalyptus,tea and deciduous soils (5.2, 5.3 and 5.1).

Profile description

Profile No.1 Deciduous forest

Higher category of classification :	Hapludolls
Soil name	Kottur Kallar association
Date of examination	10-2-1988

Brief description

Dark reddish brown to yellowish red clay loam profile with thin dark brown sandy surface. The influence of organic matter is high due to forest vegetation and which imparts the dark brown colour to the surface layer. Mottling increasingly noticed in the subsoil. Boulders are noticed within the profile at various stages of weathering. The profile is well drained with moderately slow internal permeability (Plate 3)

Profile description

Horizon	Depth (cm)	
1	0 - 4	Dark brown (7.5 YR 3/2 moist) sandy loam; weak fine crumb structure; friable, non-sticky, non-plastic; many fine to medium pores; many fine, common medium roots; clear smooth boundary.
II	4 - 16	Dark reddish brown (5 YR 2.5/2 moist) sandy clay loam; few small faint red (2.5 YR 4/6) mottled laterite; moderate medium crumb; medium firm, slightly sticky, slightly plastic; common medium

		pores; common fine and medium roots, gradual wavy boundary.
III	16 - 57	Yellowish red (5 YR 5/6 moist) gravelly sandy clay loam; many medium to fine distinct and faint brownish yellow (10 YR 6/8) and reddish yellow (7.5 YR 6/8) mottles; moderate medium subangular blocky structure; firm, sticky, plastic; common medium pores; few fine roots; gradual wavy boundary. Many medium to large laterite gravels present.
IV	57-120+	Yellowish red (5 YR 5/8 moist) gravelly clay loam; common medium to large distinct and clear dark red (2.5 YR 3/6) and reddish yellow (7.5 YR 6/8) mottles; moderate to strong medium subangular blocky structure; firm, sticky, plastic; common medium pores; very few very fine roots. Soft subangular, subrounded and irregular laterite boulders and gravels present; slightly hard, friable pallid zone.

(General and site information of the profile are given in Appendix- 1)

Profile No.2 Cashew plantation

Higher category of classification. : Hapludolls

Soil name : Kottur Kallar association

Date of examination : 10-2-1988

Brief description

Very dark grey medium textured loamy surface soil with dark brown to yellowish red gravelly loam in deeper layers. Moderately hard and friable pallid zone presents in the bottom horizon below a depth of 46 cm. Surface layer fairly rich in organic matter (Plate 5).

Profile description

Horizon	Depth(cm)	
I	0 - 19	Very dark grey (5 YR 3/1 moist) loam; weak fine granular to crumb structure; friable, non-sticky, non-plastic; many fine and medium pores; many medium, common fine roots; clear smooth boundary.
II	19 - 46	Dark brown (7.5 YR 3/2 moist) gravelly loam; weak medium granular to crumb structure; firm, slightly sticky, slightly plastic; many fine to medium pores; common fine,

		many medium, few coarse roots; gradual wavy boundary.
III	46 - 120+	Yellowish red (5 YR 5/8 moist) gravelly clay loam; moderate coarse subangular blocky structure; firm, slightly sticky, slightly plastic; common fine pores; few fine roots; few small faint mottles mainly red (2.5 YR 4/8), very pale brown (10 YR 7/4) and yellowish red (5 YR 5/8); moderately slow permeable; soft, friable pallid zone.

(General and site information of the profile are given in Appendix-II)

Profile No.3. Semi-evergreen forest

Higher category of classification. : Hapludolls

Soil name : Kottur Kallar association

Date of examination : 10-2-1988

Brief description

Very dark brown coarse sandy loam in surface horizon; dark reddish brown and dark red in deeper layers. The profile is well drained with slow internal permeability. Gravel content increases with depth. Slight indication of soft plinthite formation at the lower horizon below a depth of 40 cm. The surface layer is fairly rich in organic matter (Plate 7).

Profile description

Horizon	Depth (cm)	
I	0 - 10	Very dark brown (10 YR 2/2 moist) sandy loam; weak coarse crumb; friable, non-sticky, non-plastic; common medium interstitial pores; few faunal voids; many medium, common coarse roots; clear smooth boundary.
II	10 - 23	Very dark brown (10 YR 2/2 moist) sandy loam; moderate medium subangular blocky structure; friable, slightly sticky, slightly plastic; common fine pores; many medium coarse roots; clear smooth boundary.
III	23 - 42	Dark reddish brown (5 YR 3/2 moist) gravelly sandy clay loam; few fine to medium faint yellowish red (5 YR 4/8) and red (2.5 YR 4/8) mottles; moderate medium subangular blocky structure; firm, sticky, plastic; common very fine pores; few fine and medium roots; gradual wavy boundary.

IV	42 - 120+	Dark red (2.5 YR 3/6 moist) gravelly sandy clay loam; common small dark red (10 YR 3/6), red (2.5 YR 4/6) and yellowish brown (10 YR 5/8) mottles; moderate coarse subangular blocky structure; firm, sticky, plastic; common very fine tabular pores; few fine roots; Moist friable and soft pallid zone.

(General and site information of the profile are given in Appendix III)

Profile 4. Eucalyptus plantation

Higher category of classification. : Hapludells

Soil name : Kottur Kallar association

Date of examination : 10-2-1988

Brief description

Yellowish red gravelly sandy clay loam to gravelly clay soil with dark reddish brown, coarse, gravelly sandy loam surface soil; the profile is drained throughout, internal permeability is very slow; gravel percentage is comparatively high throughout the profile; coarse sand decreases with depth; slightly hard and friable plinthite formation at the bottom horizon after a depth of 55 cm (Plate 9).

<u>Profile description</u>

Horizon	Depth (cm)	
I	0 -11	Dark reddish brown (5 YR 3/3 moist) gravelly sandy loam; weak, coarse crumb structure; friable, non-sticky, non-plastic, highly porous, common medium channel and tubular voids including termite nests; many medium roots; clear wavy boundary.
II	11 - 26	Yellowish red (5 YR 4/6 moist) gravelly sandy clay loam; moderate medium sub-angular blocky structure; firm, slightly sticky, slightly plastic; few medium and common fine tubular pores; many medium roots; clear wavy boundary.
III	26 - 57	Mottled, gravelly clay loam; yellowish red (5 YR 5/6 moist) matrix with many fine and medium, distinct and prominent yellowish red (5 YR 4/8), red (2.5 YR 5/8), brownish yellow (10 YR 6/8) and yellow (10 YR 7/8) mottles; moderate medium subangular blocky structure; very firm, sticky, plastic; common very fine pores; common fine roots; gradual wavy boundary.

IV	57 - 130+	Yellowish red (5 YR 5/8 moist) generally gravelly clay, common fine, medium and large distinct brownish yellow (10 YR 6/8), dark reddish brown (5 YR 3/4) and yellowish brown (10 YR 5/8) mottles, prominent in patches; moderately strong medium sub-angular blocky structure; very firm, sticky, plastic; common very fine pores; distinct clay movement in some pores; subangular and sub rounded quartz gravel fragments, mostly less than 1 cm; few very fine roots; slightly hard and friable pallid zone.

(General and site information of the profile are given in Appendix IV)

Profile No.5 Evergreen forest

Higher category of classification: Hapludolls

Soil name : Kottur Kallar association

Date of examination : 9-2-1988

Brief description

Reddish brown gravelly sandy loam profile with very dark grey sandy loam surface and yellow weathered rock C horizon. Surface rich in litter. Gravels and coarse sand increasingly noticed with depth. The profile is well drained with moderately rapid internal permeability. Soft and friable laterite presents below a depth of 50 cm(Plate 11)

Profile description

Horizon	Depth(cm)	
I	0 - 21	Very dark grey (10 YR 3/2 moist) sandy loam; few multicoloured - mainly brownish yellow (10 YR 6/6), Yellowish brown (10 YR 5/8) and reddish yellow (5 YR 6/8) weathered stones and cobbles; weak medium crumb structure; friable, non-sticky, non-plastic; common medium interstitial pores; many coarse and medium roots; gradual wavy boundary.
II	21 - 51	Reddish brown (5 YR 4/4 moist) gravelly sandy loam; containing common medium to large distinct and rarely faint multi-coloured-yellowish brown (10 YR 6/4), very pale brown (10 YR 8/4) and yellowish brown (10 YR 5/8) stones and cobbles; moderate medium sub-angular bocky structure; firm, slightly sticky,

		slightly plastic; common medium tubular and interstitial voids; many medium and coarse root; abrupt wavy boundary.
III	51-120+	Yellow (10 YR 8/6 moist) loamy sand; weathered rock; common fine and medium, faint to locally distinct light grey (5 YR 7/1), very pale brown (10 YR 8/4) and yellowish red (5 YR 4/8) mottles; weak, medium subangular-blocky structure; friable, non-sticky, non-plastic; common medium tubular voids; few fine roots.

(General and site information are given in Appendix-V)

Profile No.6 <u>Tea plantation</u>

Higher category of classification. : Hapludolls

Soil name : Kottur Kallar association

Date of examination : 9-2-1988

<u>Brief description</u>

Dark brown gravelly sandy loam soil over laying reddish brown clay loam. Multicoloured weathered rock fragments are increasingly noticed at depth. The profile is well drained. Gravel content is more at surface borizon and decreasingly noticed with depth. Presence of slightly hard and moderately friable laterite layer after a depth of 30 cm (Plate 13).

<u>Profile description</u>

Horizon	Depth(cm)	
I	0 - 14	Very dark greyish brown (10 YR 3/2 moist) gravelly sandy clay loam; weak, medium crumb structure; friable, slightly sticky, slightly plastic; common medium interstitial pores; many fine, common medium roots; gradual smooth boundary.
II	14 - 30	Dark brown (10 YR 3/3 moist)gravelly sandy loam containing common fine to medium distinct and faint multi-coloured- mainly reddish yellow (5 YR 7/8), light red (2.5 YR 6/8) and red (2.5 YR 4/8) weathered rock fragments; moderate medium sub-angular blocky structure; firm, sticky, plastic; common medium interstitial and random tubular pores; common medium and fine roots; tongued abrupt wavy boundary.

III	30-130+	Reddish brown (5 YR 4/4 moist) clay loam; containing many medium to large distinct and rarely faint multicoloured-mainly red(2.5 YR 4/8) yellowish red (5 YR 4/8) mottles of weathered rock fragments; strong medium subangular blocky structure; very firm, sticky, plastic; common medium tubular voids; common medium and fine roots; soft, moderately friable pallid zone.

(General and site information of the profile are given in Appendix- VI)

Profile No.7. <u>Shola forest</u>

Higher category of classification. : Hapludolls

Soil name : Kottur Kallar association

Date of examination : 8-2-1988

<u>Brief description</u>

Deep well drained dark reddish brown sandy loam surface soil to 55 cm overlaying yellowish red sandy clay loam; sand fraction increasingly noticed with depth; weak structure but finer particles are strongly aggregated; well developed cutans; root distribution normal with majority within 55 cm;

gravelly below approx. 27 cm depth; presence of soft and friable laterite layer below 67 cm (Plate 15).

Profile description

Horizon	Depth(cm)	
I	0 - 12	Dark reddish brown (5 YR 3/2 moist) sandy loam; weak medium crumb structure; friable, non-sticky, non-plastic; common coarse random tubular and chamber voids; many coarse and medium roots; gradual smooth boundary.
II	12 - 27	Reddish brown (5 YR 4/4 moist) sandy loam; few weathered boulders; weak fine crumb structure;friable, slightly sticky, slightly plastic; common medium interstitial and random tubular pores; many medium roots; gradual wavy boundary.
III	27 - 56	Reddish brown (5 YR 4/3 moist) gravelly sandy loam; common medium faint to locally distinct very pale brown (10 YR 7/4) and brownish yellow (10 YR 6/6) mottles, many angular to subangular quartz gravels mostly less than 2 cm; moderate

		medium subangular blocky structure; firm, slightly sticky, slightly plastic; common fine interstitial pores; common medium and fine roots; gradual wavy boundary.
IV	56 -67	Yellowish red (5 YR 5/8 moist) gravelly sandy clay loam; mottled with dominant colours of light grey (7.5 YR 7/0) and yellowish red (5 YR 5/8) medium moderate subangular blocky structure; firm, sticky, plastic; fainty discontinuouse clay skin and more pressure faces; common fine mica flakes; few lyptyrite rocky pieces less than 3 cm; common fine pores; few medium roots; gradual wavy boundary.
V	67 - 140+	Yellowish red (2.5 YR 5/8 moist) gravelly sandy clay loam; moderate fine subangular blocky structure; firm, sticky, plastic; very fainty discontinuous clay skin; few stone size lyptyrite rocky fragments; black micas; common fine pores;

few fine roots; soft and friable laterite.

(General and site information of the profile are given in Appendix - VII)

Profile No.8 Acacia plantation

Higher category of classification.	: Hapludolls
Soil name	: Kottur Kallar association
Date of examination	: 8-2-1988

Brief description

Dark reddish brown coarse sandy loam soil; rarely mottled; gravel and sand fractions more at the surface and decreasingly noticed with depth; partially weathered boulders and cobbles scattered below 24 cm depth; well drained profile with moderately rapid permeability (Plate 17).

Profile description

Horizon	Depth(cm)	
I	0 - 24	Dark reddish brown (5 YR 3/2 moist) gravelly sandy loam; weak coarse crumb structure; friable, non-sticky, non-plastic; common coarse random tubular and interstitial voids; many medium and fine roots, abrupt wavy boundary.

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II	24 - 79	Dark reddish brown (5 YR 3/3 moist) sandy loam; rarely medium and fine pale grey mottles, moderate medium subangular blocky structure; firm, slightly sticky, slightly plastic; few partially weathered stone and cobbles; common medium interstitial pores; common medium and fine roots; gradual smooth boundary.
III	79 - 120+	Dark reddish brown (5 YR 3/4 moist) sandy loam; medium and large distinct pale grey mottles; moderate medium subangular blocky structure; firm, slightly sticky, slightly plastic; partially weathered stones and cobbles; common fine tubular and chamber voids; few coarse and medium roots.

(General and site information of the profile are given in Appendix - VIII)

Physical characteristics

Gravel (Table 6)

In all the soil profiles, proportion of gravel was significantly high. In forest profile it ranged from 17.46 to 52.75 per cent while 24.73 to 50.48 per cent in plantation profile. The maximum value was recorded in the profile from evergreen forest (52.75%) and the minimum in shola forest (17.46%). In forest profile gravel content was more in subsurface soil and it showed an uniform increase with depth except in the case of shola forest where the increase was only upto a depth of 67 cm and thereafter a sudden decrease was noticed in its content. In plantation profile, distribution of gravel showed no definite pattern but, its content was more in the surface soil except in the case of cashew plantation where a steady increase with depth was noticed. While comparing between profiles in each eco-system, deciduous and shola forests had a higher gravel content and semi-evergreen and evergreen forests had a lesser content than their corresponding plantations.

Coarse sand (Table 6)

The coarse sand fraction in forest profile varied from 34.16 to 64.89 per cent while 28.89 to 56.67 per cent in plantation profile. The highest value of 64.89 per cent was recorded in the bottom horizon of evergreen forest

Table 6 Granulometric composition and textural ratios of soil samples

Sample No	Depth in cm	Gravel (per cent) 2 mm	Percentage on oven dry basis Coarse sand > 2 0 0 2mm	Fine sand 0 2 0 02mm	Silt 0 02-002 mm	Clay < 0 002mm	Textural name	Textural ratios Fine sand / Coarse sand	Silt / Clay	Sand+silt / Clay
		Profile No 1 Deciduous forest								
1	0 4	32 63	34 16	7 40	32 31	19 98	Sandy loam	0 22	1 62	3 70
2	4-16	36 64	35 05	11 81	20 70	27 64	Sandy clay loam	0 34	0 5	2 44
3	16-57	51 95	38 42	6 27	21 61	31 60	Cravelly sandy clay loam	0 16	0 68	2 10
4	57 120	48 81	36 24	6 79	19 35	36 19	Gravelly clay loam	0 19	0 53	1 72
		Profile No 2 - Cashe plantation								
5	0-19	38 56	3 54	9 74	30 58	19 79	loam	0 27	1 55	3 83
6	19 46	46 95	36 16	14 83	24 21	20 11	Gravelly loam	0 41	20	3 74
7	46-120	4 05	33 87	12 91	20 94	30 40	Cravelly clay loam	0 38	0 67	2 15
		Profile No 3 Semi-evergreen forest								
8	0 10	26 94	53 23	11 98	18 06	11 89	Sandy loam	0 23	52	7 00
9	10 23	40 35	55 81	8 76	16 49	15 06	Sandy loam	0 16	1 09	5 37
10	23 42	46 53	43 62	8 23	16 02	29 56	Gravelly sandy clay loam	0 19	0 54	2 30
11	42 120	49 02	42 05	8 74	18 40	28 78	Gravelly sandy clay loam	0 21	0 64	2 40
		Profile No 4 - Eucalyptus plantation								
12	0 11	48 68	48 31	7 38	21 48	18 47	Gravelly sandy loam	0 15	1 16	4 18
13	11-26	44 82	34 27	9 48	19 93	28 56	Gravelly sandy clay loam	0 28	0 70	2 23
14	26-57	47 69	30 81	10 21	24 14	32 72	Gravelly clay loam	0 33	0 55	1 67
15	57-130	44 06	28 89	9 86	16 37	43 59	Gravelly clay	0 34	0 38	1 26
		Profile No 5 - Evergreen forest								
16	0-21	25 62	47 81	15 20	15 15	16 84	Sandy loam	0 32	0 90	4 64
17	21-51	52 75	51 42	13 98	11 69	19 72	Gravelly sandy loam	0 27	0 59	3 91
18	51-120	41 43	64 89	12 87	10 23	11 80	Loamy sand	0 20	0 87	7 46
		Profile No 6 - Tea plantation								
19	0-14	50 48	41 40	14 14	16 28	23 87	Gravelly sandy clay loam	0 34	0 68	3 01
20	14-30	44 95	43 07	10 37	17 36	26 44	Gravelly sandy clay loam	0 24	0 66	2 68
21	30-130	38 92	40 86	10 05	16 91	31 51	Clay loam	0 25	0 54	2 15

(contd)

Table 6 (contd)

Sample No	Depth in cm	Gravel (per cent) > 2mm	Percentage on oven dry basis				Textural name	Textural ratios		
			Coarse sand 2 0 0 2mm	Fine sand 0 2 0 02mm	Silt 0 02 002 mm	Clay < 0 002mm		Fine sand / Coarse sand	Silt / Clay	Sand+silt / Clay
		Profile No 7 - Shola forest								
22	0-12	20 00	44 68	9 42	28 32	11 84	Sandy loam	0 21	2 39	6 96
23	12-27	17 46	45 25	9 94	24 95	16 36	Sandy loam	0 22	1 53	4 90
24	2 56	49 52	47 02	11 67	19 23	19 79	Gravelly sandy loam	0 25	0 97	3 94
25	56 67	51 38	47 70	12 43	12 47	29 14	Gravelly sandy clay loam	0 26	0 43	2 49
26	67-140	28 83	51 45	13 09	14 86	20 00	Gravelly sandy clay loam	0 25	0 74	3 97
		Profile No 8 - Acacia plantation								
27	0-24	31 47	56 67	6 82	21 65	10 79	Gravelly sandy loam	0 12	2 01	7 89
28	24-79	29 21	50 10	11 98	22 04	12 66	Sandy loam	0 24	1 74	6 64
29	79-120	24 73	43 78	17 33	19 96	17 17	Sandy loam	0 40	1 16	4 72

profile whereas the lowest value was in the bottom horizon of eucalyptus plantation profile. In evergreen and shola forests, coarse sand fraction increased with depth while in eucalyptus and acacia plantations it decreased with depth. In the remaining sites, coarse sand content was highest in the middle horizons 10 to 57 cm depth. There was no significant difference in the average content of coarse sand between forest and plantation profiles in deciduous and shola ecosystems while in the case of semi-evergreen and evergreen ecosystems, they differed significantly.

<u>Fine sand</u> (Table 6)

The fine sand fraction ranged from 17.33 per cent in acacia plantation to 6.27 per cent in deciduous forest. In shola and its corresponding acacia plantation, fine sand content uniformly increased with depth while in evergreen forest and tea plantation, it decreased with depth. No definite pattern of distribution was noticed in the case of other profiles. Significant difference in the average content of fine sand was noticed between profiles within deciduous ecosystem (deciduous forest and cashew plantation) whereas in other ecosystems no marked difference was noticed.

Silt (Table 6)

Silt content of different soil profiles under study showed no definite pattern of distribution but in most cases the surface layer contained higher percentage of silt than the subsurface soil. The highest value of 32.31 per cent was observed in deciduous forest while the lowest value of 10.23 per cent in evergreen forest.

Clay (Table 6)

The clay content of the soil samples from forest profile ranged from 11.80 per cent (lowest horizon of evergreen forest) to 36.19 per cent (lowest horizon of deciduous forest) while 10.79 per cent (1st horizon of acacia plantation) to 43.59 per cent (lowest horizon of eucalyptus plantation) in plantation profile. In forest profile, clay content increased with depth upto the penultimate horizon and in the lowest horizon it decreased except in the case of deciduous forest where it increased steadily with depth. In plantation profile, the clay content increased uniformly down the horizon.

The greatest difference in the average content of clay was found between evergreen forest (16.12%) and tea plantation (27.27%) while in deciduous, semi-evergreen and shola ecosystems no significant difference was noticed between forest and plantation profiles.

Textural ratios

Fine sand/ coarse sand

The textural ratio of various horizons of different soil profiles are given in Table 6. The fine sand/coarse sand ratio of forest soil ranged from 0.16 to 0.34 while 0.12 to 0.41 in plantation soil. The ratio showed no definite trend over depth. Marked difference in the ratio was found between forest and plantation profiles in deciduous ecosystem while in other ecosystems the difference was marginal.

Silt/Clay (Table 6)

The silt/clay ratio of forest soils ranged from 0.43 to 2.39 while 0.38 to 2.01 in plantation soils. Between profiles within each ecosystem, no significant difference was evident.

Sand + silt/ clay ratio (Table 6)

The sand + silt/clay ratio of forest soil varied from 1.72 to 7.46 while 1.26 to 7.89 in plantation soil. In most profiles, the ratio showed a declining trend with depth. There was no significant difference in the ratio between forest and plantation soils within each ecosystem except in the case of evergreen ecosystem where significant difference was noticed.

Single value constants

Bulk density (Table 7)

The bulk density of surface horizons of forest profile ranged from 1.07 to 1.23 while 1.17 to 1.28 in plantation profile. For surface soil, bulk density was found to be lower at forest sites as compared to that of the corresponding plantation sites. Generally, the bulk densities of forest soils were found to be higher in the subsurface horizons than in the surface horizons while a reverse trend was evident in most of the plantation soils. There was not much difference between profiles in each ecosystem.

Particle density (Table 7)

The particle density of forest soil ranged from 1.86 to 2.16 while 1.86 to 2.15 in plantation soil. The particle density was found to be slightly higher for subsurface horizons than for the surface horizons. There was not much difference in particle density between profiles within each ecosystem.

Porosity (Table 7)

The porosity of soil samples from both forest and plantation sites was found high in the upper horizons than in the lower horizons, values ranging from 34.80 to 46.24 per cent. There was not much difference in porosity between

Table 7 Physical properties of soil samples

Sample No	Depth in cm	Bulk density	Particle density	Pore space (%)	Maximum water holding capacity (%)	Volume expansion (%)	Aggregate stability (%)	Mean weight diameter (mm)
	Profile No 1 Deciduous forest							
1	0 4	1 07	1 86	45 58	40 88	7 46	80 5	2 83
2	4-16	1 12	1 95	44 18	41 32	6 30	96 62	3 52
3	16-57	1 19	2 16	45 28	42 49	7 51	83 91	2 82
4	57 120	1 18	1 96	40 17	37 37	10 29	71 10	2 90
	Profile No 2 Cashew Plantation							
5	0-19	1 17	1 86	42 88	37 38	7 85	79 47	2 62
6	19-46	1 16	2 07	44 24	37 00	5 57	68 57	2 36
7	46-120	1 17	1 83	38 83	32 79	8 32	77 03	2 81
	Profile No 3 Semi-evergreen forest							
8	0-10	1 22	1 97	40 78	34 53	3 83	89 66	3 73
9	10-23	1 22	1 99	39 40	38 47	4 07	80 95	3 91
10	23 42	1 25	2 02	40 42	38 90	5 80	75 91	3 91
11	42-120	1 23	2 11	41 28	38 39	6 38	41 57	4 08
	Profile No 4 Eucalyptus plantation							
12	0-11	1 24	2 10	41 23	32 32	5 94	54 27	3 27
13	11-26	1 14	1 86	39 26	38 01	5 55	68 99	3 54
14	26 57	22	1 9	37 86	37 59	5 71	87 27	3 40
15	57-130	1 23	1 95	38 08	37 77	8 02	65 78	2 31
	Profile No 5 Evergreen forest							
16	0-21	1 10	2 06	43 76	40 08	4 11	81 74	2 70
17	21-51	1 20	1 98	40 98	33 51	4 71	63 54	3 23
18	51 120	1 26	1 97	34 80	26 40	3 84	52 11	3 34
	Profile No 6 Tea plantation							
19	0 14	1 17	2 14	44 94	37 07	4 00	56 79	2 51
20	14-30	1 13	2 12	39 34	30 99	4 01	31 58	2 82
21	30-130	1 16	2 00	42 69	34 37	5 24	82 65	3 52
	Profile No 7 Shola forest							
22	0-12	1 23	2 14	42 65	35 34	8 44	73 44	3 19
23	12 27	1 17	2 09	44 93	38 38	5 87	88 93	2 05
24	27-56	1 26	2 00	37 51	29 15	4 89	28 57	4 49
25	56 67	1 21	2 00	40 86	33 87	5 26	21 26	2 56
26	67-140	1 28	2 00	36 29	30 7	4 45	47 29	2 22
	Profile No 8 Acacia plantation							
27	0-24	1 28	2 11	40 11	30 05	4 92	83 44	3 10
28	24-79	1 17	2 15	46 24	37 46	4 37	75 30	2 84
29	79-120	1 13	1 97	43 00	36 07	4 70	84 72	2 81

profiles within each ecosystem.

Water holding capacity (Table 7)

The water holding capacity was found higher in upper and middle horizons of most of the forest profiles while in plantation profiles no specific pattern was evident. No marked difference was noticed between profiles within each ecosystem.

Volume expansion (Table 7)

The volume expansion of the soils was found to range from 3.83 to 10.29. There was not much difference in volume expansion between profiles within each ecosystem.

Aggregate analysis

Aggregate stability (Table 7)

Aggregate stability percentage of forest soils varied from 21.26 (shola) to 96.62 (deciduous) while 31.58 (tea) to 87.27 (eucalyptus) in plantation soils. In forest profile, aggregate stability was found to be more in the upper horizons than in the lower horizons while a reverse trend was evident in plantation profile. Though there was not much difference in the stability percentage between profiles within each ecosystem, the forest profiles, except shola, showed a higher value than the corresponding plantation profiles.

Mean weight diameter (Table 7)

In forest soil, the mean weight diameters were within a range of 2.05 to 4.49 mm (shola) while in the plantation soil, it ranged from 2.31 to 3.54 mm(eucalyptus). In forest profile, the mean weight diameter was found to be higher in the lower horizons than in the surface horizons but in plantation profile, except tea, a reverse trend was evident. Within each ecosystem forest and plantation profiles showed only marginal differences. In all the cases the surface soils of forest had a larger mean weight diameter than that of the corresponding plantation.

Chemical properties

pH (in distilled water)

The pH of soil samples of different profiles in distilled water showed an acid reaction, the value ranging from 4.2 to 6.4. In forest profile it varied from 4.2 to 4.9 while in plantation profile 4.2 to 6.4. In profiles from evergreen and shola forests lower horizons recorded an increase in pH, whereas in other profiles the value decreased from surface downwards. The mean value of pH from tea plantation was significantly higher as compared to that of the corresponding forest profile (evergreen) while in cashew and acacia plantations the increase over their respective forest profile was marginal. The eucalyptus plantation on the other hand had a relatively lower mean value than that of corresponding semi-evergreen forest (Table 8).

pH (in N NaF)

The pH in NaF of all the soil samples was higher than that in distilled water. In the neutral salt solution the pH increased by about 2.7 (evergreen forest) to 6.4(shola forest) unit as compared to that in water in the case of forest profiles while 1.6 (tea plantation) to 6.6(cashew plantation) units in plantation profiles. The maximum value of 11.2 was recorded in the 2nd horizon of cashew plantation, whereas the minimum of 7.4 in the 1st horizon of evergreen forest. No significant difference was noticed in the pH value between profiles within each ecosystem (Table 8).

pH(in N KCl)

The pH in N KCl solution of all the soil samples was lower than that in water. In shola forest profile, the 3rd and 4th horizons recorded a higher pH than the other horizons of the profile and in evergreen forest a constancy of pH in successive horizons was noticed. In other profiles the value decreased from surface downwards although there

Table 8 Soil reaction electrical conductivity and cation exchange capacity of soil samples

Sample No	Depth in cm	Soil ı (1 5)				Electrical conductivity (1 2 5) m mhos cm	Cation exchange capacity CMol(p^+)kg 1
		Distilled water	N Sodium fluoride	N Potassium chloride	0 01M calcium chloride		
	Profile No 1 Deciduous forest						
1	0-4	4 9	8 4	4 3	4 3	0 15	12 81
2	4-16	4 2	9 4	4 0	3 8	0 10	11 13
3	16-57	4 2	9 8	4 0	3 8	0 05	7 77
4	57-120	4 2	9 8	4 0	3 7	0 05	11 13
	Profile No 2 Cashew plantation						
5	0-19	4 8	10 6	4 2	4 5	0 16	15 75
6	19-46	4 6	11 2	4 2	4 1	0 06	11 34
7	46-120	4 2	9 7	4 1	4 0	0 05	10 92
	Profile No 3 Semi-evergreen forest						
8	0 10	4 7	7 5	4 4	4 2	0 10	10 92
9	10 23	4 6	9 3	4 1	3 9	0 07	10 92
10	23 42	4 4	10 2	4 1	3 9	0 05	9 45
11	42-120	4 3	9 8	4 0	3 9	0 04	6 93
	Profile No 4 Eucalyptus plantation						
12	0-11	4 6	7 7	4 2	4 1	0 09	9 24
13	11-26	4 3	8 8	4 0	3 8	0 07	8 86
14	26-57	4 3	9 5	4 0	3 7	0 06	7 56
15	57-130	4 2	9 8	3 9	3 7	0 04	10 69
	Profile No 5 Evergreen forest						
16	0 21	4 7	7 4	4 0	4 1	0 08	6 51
17	21-51	4 4	9 6	4 0	3 9	0 04	7 14
18	51 20	4 6	7 5	4 0	4 1	0 04	4 20
	Profile No 6 Tea plantation						
19	0-14	6 4	8 0	6 3	6 0	0 21	6 72
20	14-30	6 0	8 2	5 8	5 7	0 18	6 72
21	30-130	4 4	8 6	4 1	4 0	0 07	6 51
	Profile No 7 Shola forest						
22	0-12	4 2	8 0	4 0	3 8	0 11	8 19
23	12 27	4 2	10 0	4 0	3 8	0 06	9 66
24	27-56	4 4	10 8	4 2	4 0	0 05	7 77
25	56-67	4 4	10 4	4 1	3 9	0 04	9 03
26	67-140	4 2	9 1	4 0	3 8	0 04	8 50
	Profile No 8 Acacia plantation						
27	0-24	4 9	9 0	4 4	4 3	0 06	8 61
28	24-79	4 5	11 1	4 2	4 0	0 04	8 34
29	79 120	4 4	10 6	4 2	4 0	0 04	6 82

was not much difference in pH of the surface and subsurface soils as compared with that in water. Significant difference in the mean value of the pH was observed between profiles in evergreen ecosystem while the difference was marginal between profiles within other ecosystems.

pH (in 0.01M $CaCl_2$)

The pH in 0.01M $CaCl_2$ solution of all the soil samples recorded a lower value and in general, showed a trend quite similar to that in K Cl (Table 8).

Conductivity (Table 8)

In general the conductivity recorded a decreasing value with depth irrespective of the profiles. There was no significant difference in conductivity between forest and plantation profiles within each ecosystem.

Cation exchange capacity (Table 8)

The CEC was found to be very low in all the profiles studied, value ranging from 4.2 to 12.81 $Cmol(p^{+})kg^{-1}$ in forest profile while 6.51 to 15.75 $Cmol(p^{+})\ kg^{-1}$ in plantation profile. In semi-evergreen forest, cashew, tea and acacia plantations, CEC was found to decrease with depth while in deciduous and eucalyptus plantations the lowest horizon recorded an increase in value. In evergreen forest profile the highest value was noticed in the middle horizon. With regard to CEC no significant difference was noticed between forest and plantation profiles within each ecosystem but in general, a higher value was observed for surface soils of plantation profile than for their corresponding forest profile except in the case of semi-evergreen ecosystem where the surface soil of eucalyptus plantation had a lower value than that of the semi-evergreen forest.

Organic carbon

The percentage of organic carbon is presented in Table 9. The maximum organic carbon percentage was found to be 3.05 in the surface horizon of deciduous forest while the minimum of 0.12 per cent in the lowest horizon of evergreen forest. In all the profiles, organic carbon content was found to decrease steadily with depth. Within each ecosystem there was no significant difference between forest and plantation profiles but, in general a lower value for surface soils and a higher value for subsurface soils were observed in all the plantation profiles as compared to that of the corresponding forest profiles.

Total and available nitrogen

Table 9 presents the distribution of total and available nitrogen in various horizons of different soil profiles. The total nitrogen content of the surface soil

Table 9 Chemical characteristics of soil samples- Organic carbon N P K Ca and Mg

Sample No	Depth (cm)	Organic carbon (%)	Nitrogen		Phosphorus		Potassium		Calcium total	Magnesium total	C/N ratio
			Total %	Available $\mu g\ g^{1}$	Total %	Available $\mu g\ g^{1}$	Total %	Available $\mu g\ g^{1}$	$\mu g\ g^{1}$	$\mu g\ g^{-1}$	
	Profile No 1 Deciduous forest										
1	0-4	3 05	0 26	104	0 038	6 6	0 234	261	256	1026	11 7
2	4-16	2 24	0 20	94	0 043	2 9	0 237	45	139	806	11 2
3	16-57	1 12	0 12	89	0 129	0 6	0 135	50	61	582	9 3
4	57-120	0 83	0 09	80	0 031	1 4	0 209	38	78	533	9 2
	Profile No 2 Cashew plantation										
5	0-19	2 60	0 24	93	0 187	1 8	0 227	246	251	1015	10 8
6	19-46	1 96	0 20	88	0 086	2 4	0 371	76	58	1141	9 8
7	46-120	0 85	0 11	54	0 053	3 9	0 199	23	56	612	7 7
	Profile No 3 Semi-evergreen forest										
8	0-10	2 81	0 22	91	0 036	3 0	0 318	114	135	1065	12 8
9	10-23	2 22	0 19	74	0 054	2 0	0 305	59	79	1070	11 7
10	23-42	1 03	0 11	65	0 117	0 2	0 348	44	283	1070	9 4
11	42 120	0 70	0 07	85	0 074	0 2	0 260	43	126	964	10 0
	Profile No 4 Eucalyptus plantation										
12	0-11	2 53	0 24	118	0 113	3 1	0 196	49	101	728	10 5
13	11-26	2 18	0 18	100	0 213	1 0	0 245	39	35	802	12 1
14	26-57	1 39	0 13	82	0 068	1 0	0 236	46	126	823	10 7
15	57-130	0 98	0 11	76	0 058	1 2	0 274	44	45	773	8 9
	Profile No 5 Evergreen forest										
16	0-21	2 90	0 22	121	0 064	3 0	0 180	182	63	1182	13 2
17	21-51	1 85	0 20	102	0 073	6 9	0 204	99	27	1172	9 3
18	51-120	0 12	0 05	25	0 051	5 5	0 138	173	90	112	2 4
	Profile No 6 Tea plantation										
19	0-14	2 50	0 23	104	0 057	17 1	0 195	139	1070	4467	10 9
20	14-30	1 60	0 18	92	0 089	11 0	0 142	95	801	3832	8 9
21	30-130	0 39	0 06	75	0 106	1 0	0 075	97	36	316	6 5
	Profile No 7 Shola forest										
22	0-12	3 01	0 25	165	0 057	1 6	0 209	116	173	1670	12 0
23	12-27	1 85	0 17	108	0 034	trace	0 280	65	05	2156	10 9
24	27 56	1 13	0 12	79	0 171	0 2	0 311	53	43	2061	9 4
25	56-67	0 73	0 08	66	0 143	trace	0 249	51	115	1467	9 1
26	67-140	0 35	0 03	61	0 076	0 6	0 130	46	39	487	11 6
	Profile No 8 Acacia plantation										
27	0-24	2 36	0 24	63	0 134	0 4	0 254	152	101	3144	9 8
28	24-79	1 67	0 19	78	0 0 9	trace	0 290	55	44	3468	8 8
29	79-120	0 92	0 12	78	0 115	trace	0 328	54	29	3227	7 7

of forest profiles varied from 0.26 to 0.22 per cent while 0.24 to 0.23 per cent in plantation profiles. In all the profiles, percentage of nitrogen was found to decrease with depth. Though the content of nitrogen did not differ significantly among the profiles, its value averaged over depth was relatively higher in almost all plantation profiles as compared to that of the corresponding forest profiles, the greatest difference (0.053%) being noticed in shola ecosystem followed by semi-evergreen (0.0175%), deciduous (0.0155%) and the least (zero) in evergreen ecosystem. Moreover, in all the plantation profiles, percentage of total nitrogen showed a comparatively higher value in the lower horizons than that of the respective forest profiles.

The available nitrogen content showed no significant difference between forest and plantation profiles in each ecosystem. Ir almost all profiles percentage of available nitrogen decreased with depth except in semi-evergreen forest and acacia plantation, where the lowest horizon showed an increase in the value.

Carbon-Nitrogen Ratio

The C/N ratio varied from 2.4 to 13.2(evergreen forest). The surface soil of forest profile showed a relatively higher value as compared with that of respective plantation profile. In all the profiles C/N ratio declined uniformly with depth except in the case of semi-evergreen and shola forests where the lowest horizon showed an increase in the ratio (Table 9). The C/N ratio did not differ significantly between profiles within each ecosystem.

Total and available phosphorus

The total and available phosphorus status of the different soil profiles are presented in Table 9. The total content of phosphorus in forest soil ranged from 0.031 to 0.171 per cent while 0.039 to 0.213 per cent in plantation soil. In forest profile, phosphorus was found to accumulate in the middle horizons whereas in plantation profile its distribution did not follow a regular pattern. The average value of total phosphorus in plantation profile was slightly higher as compared to that of the corresponding forest profile while in the acacia plantation the value was slightly lower than that in the shola forest.

The available phosphorus status of the different soil profiles varied from trace to 17.1 $\mu g\ g^{-1}$. Though no regular pattern of distribution was evident its content in general, was more in the upper horizons irrespective of the profile. Between profiles in each ecosystem no significant difference was noticed in the content of available phosphorus.

Total and available potassium

The total and available contents of potassium are shown in Table 9. The total content of potassium in forest soil ranged from 0.130 to 0.348 per cent while 0.075 to 0.371 per cent in plantation soil. In forest and older plantations (cashew and tea) profiles, potassium was found concentrated in the upper horizons, whereas in young plantation (eucalyptus and acacia) profiles it accumulated more in the lower horizons. The average content of potassium did not differ significantly between profiles within each ecosystem but its value was slightly higher in cashew and acacia soils and slightly lower in eucalyptus and tea soils than their respective forest soils.

The available potassium status of forest soil ranged from 38 to 261 $\mu g\ g^{-1}$ (deciduous forest) while 23 to 246 $\mu g\ g^{-1}$ (cashew) in plantation soil. Irrespective of the profile, available potassium was found to accumulate more in the surface horizons. The distribution of average content of available potassium was found to be the same as that observed in the case of total potassium.

Calcium and Magnesium (Table 9)

The calcium and magnesium status of various horizons of different profiles ranged from 27 (evergreen forest) to 1070 $\mu g\ g^{-1}$ (tea plantation) and 112 (evergreen) to 4467 $\mu g\ g^{-1}$

(tea plantation) respectively. In many profiles their distribution showed a declining trend with depth. Significant difference in the content of calcium was found between evergreen forest and its corresponding plantation, whereas in the case of magnesium marked difference was noticed between evergreen forest and tea plantation and between shola forest and acacia plantation in evergreen and shola ecosystems respectively. Within other ecosystems the difference in the content of calcium and magnesium was marginal.

Fertility status

The fertility status of forest soil and corresponding plantation soil are presented in Table 10. In most cases surface soils of forest were superior in organic matter content than the corresponding plantation soils. In forest soil organic matter content ranged from 5.25 per cent (1st horizon of deciduous forest) to 0.21 per cent (lowest horizon of evergreen forest) while 4.48 per cent (1st horizon of cashew plantation) to 0.67 per cent(lowest horizon of tea plantation) in plantation soil. In all the profiles, organic matter was found to decrease with depth. No significant difference was noticed in the content of organic matter among the profiles. The average contents of nitrogen and phosphorus showed a higher value for the

Table 10 Fert lity status of soil profiles

Sample No	Depth in cm	pH (1 5) in distilled water	Per cent on oven dry basis				
			Organic carbon	Organic matter	Total Nitrogen	Total Phosphorus	Total potassium
	Profile No 1 Deciduous forest						
1	0-4	4 9	3 05	5 25	0 26	0 038	0 234
2	4-16	4 2	2 24	3 86	0 20	0 043	0 237
3	16 57	4 2	1 12	1 93	0 12	0 129	0 135
4	57-120	4 2	0 83	1 43	0 09	0 031	0 209
	Profile No 2 Cashew plantation						
5	0 19	4 8	2 60	4 48	0 24	0 187	0 227
6	19-46	4 6	1 96	3 38	0 20	0 086	0 371
7	46 120	4 2	0 85	0 95	0 11	0 053	0 199
	Profile No 3 Semi evergreen forest						
8	0 10	4 7	2 81	4 84	0 22	0 036	0 318
9	10 23	4 6	2 22	3 83	0 9	0 054	0 305
10	23-42	4 4	1 03	1 78	0 1	0 117	0 348
11	42 120	4 3	0 70	1 21	0 07	0 074	0 260
	Profile No 4 Eucalyptus plantation						
12	0-11	4 6	2 53	4 36	0 24	0 113	0 196
13	11 26	4 3	2 18	3 76	0 18	0 213	0 245
14	26 57	4 3	1 39	2 40	0 13	0 068	0 236
15	57 130	4 2	0 98	2 03	0 11	0 058	0 274
	Profile No 5 Evergreen forest						
16	0-21	4 7	2 90	5 00	0 22	0 064	0 180
17	21 51	4 4	1 85	3 19	0 20	0 073	0 204
18	51-120	4 6	0 12	0 21	0 05	0 051	0 138
	Profile No 6 Tea plantation						
19	0-14	6 4	2 50	4 31	0 23	0 057	0 195
20	14-30	6 0	1 60	2 76	0 18	0 089	0 142
21	30-130	4 4	0 39	0 67	0 06	0 106	0 075
	Profile No 7 Shola forest						
22	0-12	4 2	3 01	5 19	0 25	0 057	0 209
23	12 27	4 2	1 85	3 19	0 17	0 034	0 280
24	27-56	4 4	1 13	1 95	0 12	0 171	0 311
25	56-67	4 4	0 73	1 26	0 08	0 143	0 249
26	67-140	4 2	0 35	0 60	0 03	0 076	0 130
	Profile No 8 Acacia plantation						
27	0 24	4 9	2 36	4 07	0 24	0 134	0 254
28	24-79	4 5	1 67	2 88	0 19	0 039	0 290
29	79-120	4 4	0 92	1 59	0 12	0 115	0 328

plantation profiles than for the corresponding forest profiles. No marked difference was noticed in the status of potassium between profiles within each ecosystem.

Distribution of iron and aluminium in soils

Table 11 presents the distribution of various forms of iron and aluminium down the profile at different sites.

Total iron

The total iron percentage in forest soil varied from 0.636 (lowest horizon of evergreen) to 3.485 (middle horizon of shola) while 2.267 (1st horizon of cashew) to 4.772 (middle horizon of acacia) in plantation soil. In general, the total iron content was found to be concentrated in the lower horizons than in the upper horizons in all the profiles except in the case of acacia and evergreen profiles. The average value of total iron was found more in plantation profile than in the corresponding forest profile. Significant difference in the total content of iron was noticed between profiles within semi-evergreen, evergreen and shola ecosystems while no marked difference was observed within the deciduous ecosystem.

Water soluble iron

In the forest soil, water soluble iron content varied from trace to 14 $\mu g\ g^{-1}$ (deciduous) while that in the

Table 11 Chemical characteristics of soil samples - Iron and aluminium

Sample No	Depth in cm	Total (g $100g^{-1}$)	IRON $\mu g\ g^{-1}$					Active iron ratio*	Total g $100g^{-1}$	ALUMINIUM $\mu g\ g^{-1}$		
			Water soluble	Ammonium acetate extractable (exchange able)	DTPA extract able	Dithionite extractable	Oxalate extract able			Water soluble	Ammonium acetate extractable (exchange able)	DTPA extract able
		Profile No 1 Deciduous forest										
1	0 4	2 740	8	154	218	8820	2450	0 28	7 928	63	146	116
2	4-16	2 477	14	98	388	12260	2930	0 24	8 571	155	125	566
3	16-57	2 751	3	66	45	18490	3200	0 17	9 816	53	280	10
4	57 120	3 120	trace	42	38	23 00	2310	0 10	10 974	2	183	6
		Profile 2 Casnew plantation										
	0 19	2 267	11	192	398	11480	3060	27	7 497	102	284	486
6	19 46	2 871	12	103	188	13700	3450	0 25	10 182	102	246	247
7	46-120	4 074	1	31	11	30460	5660	0 19	11 033	3	186	3
		Profile No 3 Semi-evergreen forest										
8	0 10	2 002	8	128	159	7610	2320	0 30	7 427	72	63	159
9	10-23	2 178	8	115	174	9490	2700	0 28	8 859	83	122	161
10	23 42	2 379	1	69	61	13250	2950	0 22	10 520	62	160	25
11	42-120	2 428	trace	41	25	15150	2850	0 19	10 871	15	167	12
		Profile No 4 Eucalyptus plantation										
12	0-11	3 095	8	147	132	20120	2620	0 13	7 928	69	143	91
13	11-26	3 291	8	96	323	21140	3120	0 15	11 208	67	128	279
14	26-57	3 523	trace	74	23	26790	2850	0 11	13 577	19	145	6
15	57-130	3 348	trace	45	7	24650	2590	0 11	14 082	8	304	42
		Profile No 5 Evergreen forest										
16	0-21	1 442	5	131	145	5480	2070	0 38	5 333	63	162	28
17	21-51	1 910	4	79	34	9140	2720	0 30	8 141	69	67	8
18	51-120	0 636	trace	43	3	1100	190	0 17	4 853	6	86	5
		Profile 6 Tea plantation										
19	0-14	2 719	14	59	13	12630	2590	0 21	7 665	94	75	31
20	14-30	2 799	50	33	trace	12830	2460	0 19	8 152	185	43	4
21	30-130	2 957	trace	24	10	20020	1080	0 05	9 837	3	225	2

Contd

Table 11 (contd)

Sample No	Depth in cm	IRON Total (g 100g^{-1})	IRON $\mu g\ g^{-1}$ Water soluble	Ammonium acetate extractable (exchangeable)	DTPA extractable	Dithionite extractable	Oxalate extractable	Active iron ratio*	Total g 100g^{-1}	ALUMINIUM $\mu g\ g^{-1}$ Water soluble	Ammonium acetate extractable(exchangeable)	DTPA extractable
		Profile No 7 Shola forest										
22	0 12	2 213	3	142	439	11110	4190	0 38	6 124	25	126	179
23	12-27	3 130	1	81	259	14790	5640	0 38	9 192	20	106	147
24	27-56	3 485	3	58	99	18210	5590	0 31	10 487	115	103	91
25	56-67	3 465	2	47	22	25440	3720	0 15	10 573	12	105	15
26	67-140	3 180	trace	28	12	24390	1980	0 08	14 213	2	155	9
		Profile No 8 Acacia plantation										
27	0-24	4 250	15	142	456	18100	4010	0 22	9 530	35	150	388
28	24-79	4 772	9	87	77	25570	7030	0 27	11 837	30	101	220
29	79-120	4 091	trace	29	88	31160	10470	0 34	11 531	13	142	5

* Ratio of oxalate to dithionite extractable iron

plantation soil it ranged from trace to 50 $\mu g\ g^{-1}$ (tea). The maximum content of water soluble iron was observed in the upper and middle horizons while in the lowest horizon its amount was practically zero. There was significant difference in the content of water soluble iron between profiles within the evergreen ecosystem. In other ecosystems the difference between profiles was marginal.

Exchangeable iron (Ammonium acetate extractable)

The exchangeable iron content varied from 28(shola) to 154 $\mu g\ g^{-1}$ (deciduous) in forest soil, whereas in plantation soil the variation was from 24(tea) to 192 $\mu g\ g^{-1}$ (cashew). In all the cases its distribution showed a steady decrease with depth. There was no marked difference between profiles within each ecosystem.

DTPA extractable iron

The DTPA extractable iron content in the forest soil varied from 3 (evergreen) to 439 $\mu g\ g^{-1}$ (shola) while trace (tea) to 456 $\mu g\ g^{-1}$ (acacia) in plantation soil. Irrespective of the profile, the content of DTPA extractable iron was found to decrease with depth. No marked difference was noticed in the content of iron among the profiles.

Dithionite extractable iron

The dithionite extractable iron content in the forest soil ranged from 5480 (evergreen) to 25440 $\mu g\ g^{-1}$ (shola) while 11480 (cashew) to 31160 $\mu g\ g^{-1}$ (acacia) in plantation soil. The distribution in successive horizons in general was found to increase with depth in most profiles. Significant difference in the content of free iron oxide was noticed between profiles within the semi-evergreen ecosystem. No marked difference was observed between forest and plantation profiles within other ecosystems. The average content of the free iron oxide in plantation profile showed a comparatively higher value than the corresponding forest profile.

Oxalate extractable iron

The oxalate extractable iron in forest soil constituted 190 (evergreen) to 5640 $\mu g\ g^{-1}$ (shola) while 1080 (tea) to 10470 $\mu g\ g^{-1}$ (acacia) in plantation soil. In all the forest profiles, the distribution of oxalate extractable iron followed a pattern of initial increase and a subsequent decline. The same trend was observed in eucalyptus plantation also. In cashew and acacia plantation profiles there appeared a steady increase in the value with depth while a reverse trend was noticed in tea plantation. In all the plantation profiles the average content of the oxalate extractable iron recorded a comparatively higher value than the corresponding forest profiles. Marked difference was noticed between profiles within shola ecosystem while the difference was marginal within other ecosystems.

Active iron ratio

The active iron ratio was obtained by dividing the content of oxalate extractable iron (amorphous form) by dithionite extractable iron (amorphous and crystalline). The values of active iron ratio were within the range of 0.05 to 0.38. In most profiles the values in successive horizons showed a general decrease with depth. No marked difference was noticed between forest and plantation profiles within each ecosystem.

Total aluminium

The percentage of total aluminium in forest soils ranged from 4.853 (evergreen) to 14.213 (shola) while 7.497 (cashew) to 14.082 (eucalyptus) in plantation profiles. It was found to increase with depth and a maximum concentration was observed in the lowest horizon of all the profiles except in the case of evergreen forest where the lowest horizon recorded the minimum value. The plantation profiles in general, showed a comparatively higher value of average total aluminium content than the corresponding forest profiles. There was no significant difference between forest and plantation profiles within each ecosystem.

Water soluble aluminium

Water soluble aluminium constituted 2 to 185 $\mu g\ g^{-1}$ of the soil. The value was observed to be higher in the upper horizons than in the lower. No significant difference in the content of water soluble aluminium was noticed among the profiles.

Exchangeable aluminium

The exchangeable aluminium content extracted by ammonium acetate solution varied from 43 to 304 $\mu g\ g^{-1}$ No definite pattern was evident in the distribution of the exchangeable aluminium.

DTPA extractable aluminium

The content of DTPA extractable aluminium was higher in the upper horizons than in the lower horizons. It's value ranged from 2 to 566 $\mu g\ g^{-1}$ of the soil. There was no significant difference in the content of the aluminium among the profiles.

Distribution of manganese, zinc and copper

The table 12 gives the distribution of different forms of manganese, zinc and copper in various horizons of the profiles investigated.

Manganese

The total content of manganese varied from 48 to 201 $\mu g\ g^{-1}$ (deciduous) in forest soil while 31 (Eucalyptus) to 748 $\mu g\ g^{-1}$ (acacia) in plantation soil. The concentration of total manganese was higher in the upper horizons than in the lower horizons except in the case of acacia plantation where the lowest horizon recorded the highest value. Significant difference was noticed between forest and plantation profiles within the shola ecosystem, whereas the difference was marginal within other ecosystems.

The content of exchangeable manganese extracted by ammonium acetate solution was found to decrease with depth in all the profiles. The same trend was observed in the distribution of DTPA extractable manganese but of a higher magnitude. There was no significant difference in the content of manganese among the profiles.

The amount of manganese extracted with distilled water at the pH of the soil was practically zero for all the soils studied.

Zinc

The total content of zinc varied from 37.17(evergreen) to 316.02 $\mu g\ g^{-1}$ (semi-evergreen) in forest soil and 55.94 to 306.65 $\mu g\ g^{-1}$ (eucalyptus) in plantation soil. No definite pattern was evident in the distribution of total zinc with depth.

Table 12 Chemical characteristics of soil samples - manganese zinc and copper

Sample No	Depth in cm	μg g 1											
		Manganese				Zinc				Copper			
		Total	Water solu-ble	Exchange-able	DTPA extracta-ble	Total	Water solu-ble	Exchange able	DTPA extract able	Total	Water solu-ble	Exchange-able	DTPA extract-able
		Profile No 1 Deciduous forest											
1	0-4	201	trace	10	17	220 42	2 27	5 83	2 83	28	trace	0 6	1 04
2	4-16	129	"	6	38	107 96	0 58	3 58	3 21	34	"	0 6	1 22
3	16-57	53	"	2	38	100 92	0 26	3 36	1 39	34		0 6	0 73
4	57-120	48	"	1	13	93 10	0 15	3 18	0 98	37	"	0 6	0 75
		Profile No 2 Cashew plantation											
5	0-19	94	trace	5	28	87 28	3 43	5 47	1 56	44	"	0 8	1 39
6	19-46	86	"	2	17	233 84	2 65	5 22	3 29	57	"	0 8	2 03
7	46-120	99	"	1	10	127 65	0 29	3 04	0 85	61	"	0 4	0 32
		Profile No 3 Semi evergreen forest											
8	0-10	135	trace	5	32	260 50	0 05	5 37	0 88	25		0 2	0 78
9	10-23	117	"	2	17	51 11	4 06	5 11	0 76	25	"	0 8	0 91
10	2 -4	68	"	1	14	316 02	2 86	4 26	0 67	29	"	0 6	0 69
11	42-120	59	"	1	15	116 41	1 64	3 94	0 61	36	"	1 2	1 03
		Profile No 4 Eucalyptus plantation											
12	0-11	104	trace	5	24	306 65	trace	4 69	0 92	109	"	0 6	0 98
13	11-26	63	"	2	19	55 94	3 44	3 96	0 78	35	"	0 4	0 36
14	26-57	43	"	1	13	192 37	1 56	3 34	0 46	43	"	0 6	1 25
15	57-130	31	"	1	14	172 57	2 08	2 88	5 43	49	"	0 6	0 24
		Profile No 5 Evergreen forest											
16	0-21	198	trace	20	53	55 05	4 25	5 98	0 92	20	"	1 0	0 28
17	21-51	148	"	4	15	37 17	3 23	4 60	0 41	17	"	1 0	0 08
18	51-120	85	"	2	14	305 78	1 55	4 61	1 03	278	"	1 0	0 08
		Profile No 6 Tea plantation											
19	0-14	202	trace	13	12	137 56	5 75	7 10	6 08	55	"	1 0	2 19
20	14-30	122	"	5	24	66 19	1 46	5 57	3 92	56	"	0 8	2 98
21	30-130	56	"	1	11	166 80	1 89	3 95	1 94	108	"	0 8	0 51

(contd)

Table 12 (contd)

Sample No	Depth in cm	µg g^{-}											
		Manganese				Zinc				Copper			
		Total	Water solu ble	Exchange-able	DTPA extract-able	Total	Water solu-ble	Exchange able	DTPA extract able	Total	Wate solu-ble	Exchange able	DTPA extract able
		Profile No 7 Shola forest											
22	0-12	136	trace	9	46	73 81	2 10	4 81	1 56	26	trace	0 8	1 81
23	12-27	122		2	93	107 05	4 71	4 43	1 91	33	"	0 8	1 42
24	27 56	125		1	12	60 61	1 51	4 12	0 35	41		0 8	1 29
25	56-67	130		1	16	59 60	1 37	4 10	0 47	43	"	1 0	1 17
26	67-140	58		trace	22	76 55	3 26	2 49	2 90	41	"	1 0	0 67
		Profile No 8 Acacia plantation											
27	0-24	291	trace	16	15	84 66	2 72	5 12	2 25	34	"	1 0	0 70
28	24-79	422	"	6	50	113 49	2 13	4 90	0 37	40	"	0 6	1 08
29	79-120	748		4	30	96 63	4 74	3 07	1 14	38	"	0 8	0 90

The amount of water soluble zinc varied within the range of 0.05 to 4.71 $\mu g\ g^{-1}$ in forest soil while trace to 5.75 $\mu g\ g^{-1}$ in plantation soil. No significant difference among the profiles was observed with respect to the content of total and water soluble zinc.

The concentration of exchangeable zinc extracted by ammonium acetate solution was higher in the upper horizons than in the lower. In forest soil, the exchangeable zinc varied from 2.49 to 5.98 $\mu g\ g^{-1}$ of soil while 2.88 to 7.10 $\mu g\ g^{-1}$ in plantation soil. The content of DTPA extractable zinc showed no definite pattern of distribution. Its value in forest soil ranged from 0.35 to 3.21 $\mu g\ g^{-1}$ of soil while 0.37 to 6.08 $\mu g\ g^{-1}$ in plantation soil. No marked variation in the content of these two forms of zinc was noticed between profiles within each ecosystem.

Copper

The total content of copper in forest soil ranged from 17 to 278 $\mu g\ g^{-1}$ (evergreen forest) of soil while 34 (acacia) to 109 $\mu g\ g^{-1}$ (eucalyptus) in plantation soil. The value of total copper was found to be higher in the lower horizons than in the upper horizons in all the profiles except in the case of eucalyptus plantation where the highest value was recorded in the surface horizon. There was no significant difference in the content of total copper among the profiles.

The amount of water soluble copper extracted at the pH of the soil was practically zero for all the soils studied.

The concentration of exchangeable (ammonium acetate extractable) copper of the successive horizons of the same profile did not show much variation among themselves but in plantation profile the value was slightly higher for surface soil than for subsurface soil. The value of DTPA extractable copper varied from 0.08 to 2.98 $\mu g\ g^{-1}$ of soil. The distribution with depth in most profiles followed an initial increase and a subsequent decrease. In evergreen and shola forest profiles there was a uniform decrease in the content with depth while in semi-evergreen forest profile the lowest horizon recorded a higher value than the overlaying horizons.

Mineralogy of fine sand fraction

Table 13 gives the distribution of both light and heavy mineral fractions present in various soil samples and their percentage in the fine sand fraction. The heavy mineral fraction varied from 0.31 to 2.50 per cent in forest soil while it was in the range of 0.47 to 2.79 per cent in plantation soil. It constituted about 2.5 to 19.50 per cent of the fine sand in forest soil, whereas 3.70 to 27.60 per cent of the fine sand in plantation soil. The heavy minerals were found to be lower in the lower

Table 13 Mineralogy of heavy and light fractions in fine sand

Sample No	Depth in cm	g 100g^{-1} oven dry soil			Percentage	
		Heavy fraction fine sand	Light fraction fine sand	Total fine sand	Heavy faction in fine sand	Light fraction in fine sand
	Profile No 1 Deciduous forest					
1	0-4	0 66	6 74	7 40	9 00	91 00
2	4-16	2 30	9 51	11 81	19 50	80 50
3	16 57	0 34	5 93	6 27	5 50	94 50
4	57-120	0 31	6 48	6 79	4 50	95 50
	Profile No 2 Cashew plantation					
5	0-19	2 68	7 06	9 74	27 60	72 40
6	19-46	1 89	12 94	14 83	12 80	87 20
7	46-120	1 00	11 91	12 91	7 80	92 20
	Profile No 3 Semi evergreen forest					
8	0-10	2 09	9 89	11 98	17 50	82 50
9	10-23	1 63	7 13	8 76	18 60	81 40
10	23-42	1 20	7 03	8 23	14 60	85 40
11	42-120	0 76	7 98	8 74	8 67	91 33
	Profile No 4 Eucalyptus plantation					
12	0-11	0 86	6 52	7 38	11 67	88 33
13	11-26	0 97	8 51	9 48	10 20	89 80
14	26-57	0 91	9 30	10 21	9 00	91 00
15	57-130	0 47	9 39	9 86	4 75	95 25
	Profile No 5 Evergreen forest					
16	0-21	1 52	13 68	15 20	10 00	90 00
17	21-51	1 11	12 87	13 98	8 00	92 00
18	51-120	0 32	12 55	12 87	2 50	97 50
	Profile No 6 Tea plantation					
19	0-14	2 79	11 35	14 14	19 75	80 25
20	14-30	1 34	9 03	10 37	13 00	87 00
21	30-130	1 35	8 70	10 05	3 40	86 60
	Profile No 7 Shola forest					
22	0-12	1 56	7 86	9 42	16 60	83 40
23	12-27	0 54	9 40	9 94	5 50	94 50
24	27-56	0 58	11 06	11 64	5 00	95 00
25	56 67	0 69	11 74	12 43	5 60	94 40
26	67-140	0 71	12 38	3 09	5 30	94 70
	Profile No 8 Acacia plantation					
27	0-24	0 79	6 03	6 82	11 60	88 40
28	24-79	0 71	11 27	11 98	6 00	94 00
29	79-120	0 64	16 69	17 33	3 70	96 30

horizons than in the upper horizons irrespective of the profiles.

The light mineral fraction varied from 5.93 to 13.68 per cent of the forest soil while 6.03 to 16.69 per cent of the plantation soil. The percent value of light fraction in the fine sand was comparatively higher in the lower layers. The value of heavy mineral fraction was comparatively much lower than that of the light mineral fraction in all the soil samples.

The mineralogical composition of fine sand fraction is presented in Tables 14.1, 14.2, 14.3 and 14.4. The heavy mineral fraction consisted of translucent and opaque minerals representing black opaque (including ilmenite), sillimanite, red opaque, zircon, kyanite, rutile, leucoxene, amphibole, tourmaline, monozite, chlorite, garnet, titanite and spinel. Among the heavy minerals black opaque, sillimanite, red opaque and zircon were the most dominant ones. Profiles from deciduous and semi-evergreen ecosystem and acacia plantation had a sequence of black opaque-sillimanite-red opaque-zircon while that from evergreen ecosystem and shola forest had the sequence of sillimanite-black opaque-red opaque-zircon.

The light mineral fraction chiefly comprised of quartz with a small amount of feldspars and micas except

Table 14 1 Mineralogical composition of fine sand fraction from various horizons of soil profiles - Deciduous forest and Cashew plantation

Profile and horizons No		Sample Number	Depth(cm)	Percentage of total fine sand										Remarks
				Heavy minerals								Light minerals		
				Black opaque Ilmenite	Leucoxene	Red opaque *	Zircon	Rutile	Sillimanite	Kyanite	Others	Quartz	Others	
Deciduous forest	I	1		2 75	0 50	1 25	0 75	0 25	2 75	0 75	-	91 00 Subangular and subrounded	-	
	I	2		12 50	-	-	-	-	5 50	1 50	-	80 50 Subangular and subrounded	-	
	III	3		2 75	-	0 25	0 25	-	1 75	0 50	-	94 5 (Iron coated 35% and Runic quartz 7 8%)	-	
	IV	4		1 25	-	1 0	0 25	0 25	1 75	-	-	82 25 subangular and subrounded	Mica 13 25	Greyish brown organic matter noted
Cashew Plantation	I	5		16 40	1 00	1 00	2 00	0 40	6 80		-	68 40 Uneven angular and subangular	Mica-4 00	
	II	6		5 4	0 20	1 80	2 00	0 80	1 80	0 80	-	87 20 (Iron coated 23% Angular to subangular)	-	Subrounded Ovate and platy tar brownish coatedwith organic matter 37 Nos noted
	III	7		1 00	-	1 20	-	-	1 20	0 20	Chlorite 4 2	79 60 angular to subangular	Mica 12 6	Decomposed organic matter brownish-yellow in colour with granular to play structure-noticed numerous in number

* Hematite limonite goethite

Table 14 2 Mineralogical composition of fine sand fraction from various horizons of soil profiles - Semi evergreen forest and Eucalyptus plantation

Profile and horizon No	Sample No	Depth (cm)	Percentage of total fine sand										Remarks
			Heavy minerals								Light minerals		
			Black opaque Ilmenite	Leuco xene	Red opaque *	Zircon	Rutile	Sillima nite	Kyanite	Others	Quartz	Others	
Semi evergreen forest I	8		7 90	-	2 00	0 65	0 35	1 35	2 30	Garnet - 0 65 Monozite 1 00 Pyroxene 0 65 Tourma line 0 65	79 15 Subrounded to rounded and rarely angular	Mica 3 5	Mica brown in colour
I	9		9 50		-	1 40		4 80	0 70	Monozite 0 60 Amphibole 1 60	76 60 (ferri organic coated 4%) subangular subrounded and angular	Mica 3 20 Feldspar 1 60	
III	10		10 2	-	1 40	0 60	-	2 80	0 60		76 40 Low relief platy sub-angular and subrounded	Mica 2 60 Feldspar 5 40	
IV	11		2 70	0 33	0 33	0 67	-	0 67	0 67	Amphibole 3 30	77 33 Subangular and sub-rounded	Feldspar 14 00	Brownish red decomposed organic matter platy and granular found numerous
Eucalyptus plantation I	12		7 00		1 67	1 00		2 00	-		80 67 platy angular subangular & subrounded & iron coated	Mica 7 66	
II	13		6 20	-	0 40	0 40	-	2 80	0 40		82 60 Dominantly platy rarely with high relief and iron oxide coated	Feldspar 7 20	Dark brownish organic matter flakes <0 2mm size 7 nos noticed
III	14		5 00	-	1 00	1 00	-	2.00	-		81 00 Angular to subangular	Mica 2 00 Feldspar 2 00 Brown Mica 6 00	Brownish-yellow iron coated play and decom posed organic matter (10Nos) noted
IV	15		1 50		0 50	0 50	-	1 00	0 25	Monozite 0 25 garnet -0 25 Pyroxene 0 50	95 25 Highrelief sub angular and angular having bigger size	-	-

* Hematite limonite goethite

Table14 3 Mineralogical composition of fine sand fraction from various horizons of soil profiles - Evergreen forest and Tea plantation

Profile and horizon No	Sample No	Depth(cm)	Percentage of total fine sand										Remarks
			Heavy minerals								Light minerals		
			Black opaque Ilmenite	Leucoxene	Red* opaque	Zircon	Rutile	Sillimanite	Kyanite	Others	Quartz	Others	
Evergreen forest I	16		50			1 25		00	1 25		74 75 Bigger subangular and subrounded	Brownmica 7 50 Feldspar 7 75	Brownish yellow decomposed organic matter globules with cellular features present
	17		80		1 20	0 50	0 60	2 20		Chlorite 0 20 spinel 0 40 i te 0 4 Tourmaline 0 60	86 00 Subangular and subrounded having size < 60 µ (un c quartz 6 7%)	Feldspar 6 00	
III	18		50		1 00						97 50 Subangular and subrounded		
Tea plantation I	19		25		1 25	-		8 50	25	Chlorite 1 25	77 50 Medium to low relief subangular and subrounded	Mica 2 75	Decomposed organic matter platy brownish black in colour 44 Nos present
II	20		5 80		1 60	1 40	-	3 60		Tourmaline 0 60	87 00 Low to very low relief platy subangular and subrounded	-	Platy brownish black organic matter aggregates 26 Nos noted
III	21		3 80		1 80	0 40	0 40	3 80	0 60	Spinel 0 20 garnet 0 20 Monazite 0 20 Tourmaline 0 60 Amphibole 1 40	79 00 Angular to sub-angular rarely iron coated and bigger grains >0 1 mm size	Mica 7 60	Ferriorgan plates 12 Nos noted

* Hematite limonate goethite

Table 14 4 Mineralogical composition of fine sand fraction from various horizons of soil profiles - Shola forest and Acacia plantation

Profile and horizon No		Sample No	Depth (cm)	Percentage of total fine sand										Remarks
				Heavy minerals								Light minerals		
				Black opaque Ilmenite	Leucoxene	Red* opaque	Zircon	Rutile	Sillimanite	Kyanite	Others	Quartz	Others	
Shola forest	I	2		4 40		1 40	0 80	0 40	6 00	2 80	Monozite 0 40 Tourmaline 0 40	60 00 Platy low relief iron coated with faint margin	Mica - 23 40	
	II	2		2 50			0 75		1 75	0 50		73 50 Subangular and subrounded	Mica - 14 75 Feldspar 6 25	Platy opaque to brownish black ferri-organ with reddish brown margin
	III	2		2 00	-	1 00	0 25		1 25	0 50	-	84 40 Subrounded to rounded	Feldspar 10 60	Ferri-organ platy aggregate < 0 04 mm opaque to brownish-black in colour - found numerous
	IV	2		2 00	-	1 20	0 40	-	1 60	0 20	-	84 00 Subrounded to rounded (Iron coated brownish yellow sub angular and subrounded quartz comes about 30%)	Mica - 3 40 Feldspar -7 00	
	V	26		1 80		0 25	0 25	-	2 80	0 20	-	41 00 Subangular and subrounded	Mica - 42 00 (Ironcoated) Feldspar 11 70	
Acacia plantation	I	27		8 20	-		0 40		2 40	0 40	Titanite 0 40	55 00 Subrounded to rounded and rarely subangular	Mica- 21 40 Fieldspar- 2 00	Decomposed organic matter with ferri organ 67 Nos noticed
	II	28		5 00	-	0 40	0 20		0 20		Tourmaline -0 20	68 00 Subangular and subrounded	Mica-26 00	Decomposed blackish brown ferri organ plates numerous
	III	29		2 70		0 50					-0 50	22 60 Platy and sub angular (about 60% are iron coated)	Mica 62 20 Feldspar-11 50	Blackish-brown platy organic matter present

* hematite limonite goethite

in the shola ecosystem where mica was the predominent mineral in the lowest horizon. The amount of quartz ranged from 41 to 97.50 per cent of the fine sand in forest soil while 22.6 to 95.25 per cent of fine sand in plantation soil. The average content of quartz fraction in fine sand was observed to be more in forest soil than in the corresponding plantation soil within all ecosystems except in semi-evergreen where the plantation soil had a higher average value compared to the forest soil. The quartz grains varied in size from 30 to 200 microns and had angular to subangular and sub rounded shapes irrespective of the soil. Some of the grains were seen coated with organic matter and/or oxides of iron.

There was no definite pattern of distribution for quartz while other resistant minerals like zircon and tourmaline showed a decrease with depth. The content of weatherable minerals like feldspars, micas and chlorite was found to increase with depth in all the profiles.

Micromorphology

The detailed micromorphological description of the soils in different profiles are presented in Tables 15.1 to 15.8 and related photomicrographs in plates No.18 to 68.

Table 15 1 Micromorphology of deciduous forest profile

Profile No 1	Deciduous forest			
Horizon No	1	2	3	4
Plasma	Dominantly yellowish brown and at places dark yellowish brown and light grey forms small portion of the soilmass	Yellowish brown to dark brown in colour forms major portion of the soil mass argillaceous in nature	Strong brown in colour forms major portion of the soil mass	Reddish yellow in colour dense with fractured and weathered quartz grain
Soil fabric	Skelvosepic skelsepic	Dominantly masepic skelvosepic and rarely isotic to argillasepic	Argillasepic and skelvosepic followed by insepic and isotic	Skelsepic vosepic and argillasepic
Skeleton	Angular to subangular low relief and rarely fractured quartz highly fractured biotite hornblende and feldspar observed in the concretionary lithorelic skeletons in general fractured and weathered with iron deposition in sutures	Quartz present are mostly < 0 4 mm in size subangular subrounded and rounded embedded in dense plasma forms small portion of S matrix rarely coarse sand-sized quartz present	Angular to subangular silt-sized quartz embedded in dense plasma	Angular to subangular
RDP	Chlamydomorphic	Porphyric	Porphyric	Porphyric
NRDP	Granic	Plasmic	Plasmic	Granic and plasmic
Coarser/ finer fraction	Coarser	Finer	Finer	Coarser, at places finer
Voids	Highly porous bigger in size dominantly planar and packing	Channel and chamber shaped vughs and metavughs present	Chamber and channel shaped rarely vughs and metavughs	Channel and chamber shaped vughs present
Humus	Dominantly yellowish-brown followed by dark yellowish brown plasmified melanans look like mull	Present in pockets coated with iron	Less present as microaggregates	Absent

(contd)

Table 15 1 (contd)

Profile No 1	Deciduous forest			
Horizon No	1	2	3	4
Chlamydomorphic coatings	Discontinuous yellowish brown to dark yellowish brown chalmydomorphic bridging the quartz skeletons	Absent	Absent	Absent
Lithorelics	Present subangular and subrounded blackish brown concretionary lithorelics containing hornblende biotite quartz feldspar etc All skeletons are embedded and fixed by the infilling of opaque fine iron oxide deposition	Absent	Present magnetic nodules lateritic fragments	Absent
Cutans	Ferri organan and rarely ferri-argillan at pockets	Ferri-argillan	Ferri-argillan	Ferri-argillan pure kaolinite is also observed in fissures of fragmented quartz concretions and in the channels
Special observation	Plasma forms small portion of the soil mass and present as localised plasmified iron mixed aggregates highly porous	No other minerals are observed	More plasma less skeleton	Bigger angular fractured and weathered quartz and magnetite iron nodules present channel type followed by chamber shaped voids

Table 15 2 Micromorphology of Cashew plantation profile

Profile No 2	Cashew plantation		
Horizon No	1	2	3
Plasma	Brownish yellow in colour well aggregated forms major portion of the soil mass	Brownish yellow to light grey in colour well aggregated ferri argillan observed as discrete entities	Brownish yellow in colour rarely light grey aggregated forms small portion of the soil mass
Soil fabric	Vosepic followed by skelvosepic	Skelvosepic followed by argillasepic and insepic at pockets tendency to form vosepic places of argillan aggregates	Dominantly skelsepic followed by insepic and isotic
Skeleton	Subangular and subrounded quartz embedded in dense plasma magnetite hematite and few feldspar present	Few coarse sand sized lateritic nodules present with quartz dense opaque to blackish red iron coatings subangular and subrounded few opaque minerals and rarely feldspar present	Large and fractured quartz with iron deposition in the fissures subangular and subrounded few subangular low relief opaque minerals also present
RDP	Plasmic followed by granic	Plasmic to granic	Porpyric
NRDP	Porphyric	Porphyric	Porphyric
Coarser/Finer fraction	Coarser	Finer	Coarser
Voids	Channel and chamber shaped noted the presence of one bigger channel type voids	Dominantly vughs and metavughs fine channel and chamber shaped voids are also present	Channel type followed by chamber type, rarely ortho and metavughs
Humus	Melanans- plasmified brownish yellow in colour ferri-organan present surrounding skeletons and voids	Highly decomposed plasmified well aggregated dense humus present as brownish yellow ferri organan	Brownish yellow plasmified humus present as ferri-organ aggregates surrounding the skeletons their fissures and voids
Chlamydo-morphic coatings	Absent	Present	Discontinuous clay organic bridging of skeletons not observed except at places of their aggregated field

(contd)

Table 15 2 (contd)

Profile No 2	Cashew plantation		
Horizon No	1	2	3
Litho relics	Absent	Few present	Few coarse sand-sized weathered and fractured lateritic fragments present
Cutans	Few thin layer of yellowish argillan present in the inner margin of channel type voids some fine channels are filled with translocated clay resulting in clay pluggs and papules	Absent	Argillic horizon in its initial stages of formation clay translocation and accumulation is active and the process seems a current one
Special observation	Dense and brownish yellow ferri argillan forms the major portion of the soil mass less than 30% occupied by subangular and subrounded unweathered quartz	Well aggregated dense ferri-organ and high relief lateritic nodules skeleton and lithorelic are subangular and subrounded few opaques present	Plasma forms small portion of the soil mass opaque minerals less lithorelic present are fractured with iron deposition in the fissures

Table 15 3 Micromorphology of Semi-evergreen forest profile

Profile No 3	Semi-evergreen forest			
Horizon No	1	2	3	4
Plasma	Very dusky red to reddish black and rarely light grey in colour forms about 30 40% of the soil mass low relief	Mainly dusky red dense Less denser brownish yellow also observed forms less than 10% of the soil mass	Dark red red and dense iron oxide(dominantly hematite followed by limonite) forms 40 to 50% of the soil mass and in intimate contact with the weathering mass	Dusky red to yellowish brown and white (bluish white or grey) less dense to dense forms major portion of the soil mass At places plasma is light brown to brownish yellow
Soil fabric	Skelsepic insepic and isotic	Skelsepic 70 to 80% of the soil mass is occupied by skeleton Plasmic fabric is insepic rarely isotic	Skelvosepic insepic and isotic	Insepic vosepic and voskelsepic
Skeleton	Subrounded and subangular non fractured low relief quartz hornblende and feldspar silt to fine sand in size medium to very fine silt size limonite and hematite few medium silt sized opaque minerals	Coarse silt sized low relief non-fractured subangular and subrounded quartz	Subrounded to rounded low relief quartz feldspar and hornblende	Non uniformly distributed subangular and subrounded low relief quartz present in channels lateritic nodules and concretions at places more than coarse sand sized subrounded lateritic nodules blackish red to dusky red iron oxide coating in the lateritic nodules quartz nucleii of the nodules are highly weathered and fragmented
RDP	Porphyric tending to become chlamydomorphic which is in the initial stages of its formation	granic	granic	Plasmic and granic
NRDP	Porphyric tending to become chlamydomorphic	Dominantly granic followed by plasmic/granic plasmic	granic	Plasmic granic and massive
Coarser/finer fractions	Coarser	Coarser	Coarser massive	Coarser and finer at places

(contd)

Table 15 3 (contd)

Profile No 3	Semi evergreen forest			
Horizon No	1	2	3	4
Voids	Porous and planar rarely interconnected m tavugns	Planar and packing oval voilds bigger in size fine and interconnected channels present	Planar and rarely packing surrounded by dense dark red/red/yellow iron deposition from periphery towards the centre	Channel and chamber shaped followed by orthovughs
Humus	Completely decomposed melanan aggregates present as discrete entities at places coalesced occupying more area signs of faunal activities especially that of earthworms identified by the presence of peculiar organic matter aggregation	Well aggregated dense dusky red to reddish brown plasmified organic matter present surrounding the skeleton and voids forming demarcating boundary	Absent	Absent
Chlamydomorphic coatings	Present in its initial stages of formation-bridging of the ferri organic materials is complete marginally on the fine sand skeleton	Bridging of organic materials surrounding the skeleton is complete appears to be as similar to that in the temperate podzols	Absent	Absent
Litho relics	Absent	Absent	Absent	Absent
Cutans	Dominantly ferri-organan followed by organan and ferri-argillan revealed by the faint yellowish brown to yellow margins of the coated cutanic materials on the skeletons and voids indicating the possibility of nucleation for the formation of argillic horizon is remote	Organan followed by ferri-organan ferri argillan absent no sign of accumulation (initiation) of argillaceous material	Ferran and goethans present surrounding the skeleton and voids-appearing a webby structure	Ferran ferri-argillan and argillan argillan present surrounding bigger quartz grains and bigger voids major portion is occupied by ferran yellow margins of the channels are goethite tendency to form an argillic horizon Illuviated argillans also present surrounding the channels and skeletons
Special observations	Highly weathered medium to fine sand-sized quartz	Conspicuous Chlamydomorphic formation and absence of argillan	Cleavages of feldspars hornblende quartz are partially filled with iron and clay Coating of iron oxide in a peculiar pattern observed Dark areas are impregnated with iron Higher population of quartz grains with low iron noted above the dark area	Few dense nodules with highly fractured dense nucleii present The yellow parts are crystalline goethite especially on the walls of small channel The dark streak through the centre is former channel filled with fine-grained hematite hites ots are quartz grains

Table 15 4 Micromorphology Eucalyptus plantation profile

Profile No 4	Eucalyptus plantation			
Horizon No	1	2	3	4
Plasma	Dark reddish brown forms major portion of the soil mass	Reddish brown to yellowish red forms major portion (about 60%) of the soil mass	Dark brownish to dusky reddish brown dense forms less than 40% of the soil mass	Dark brownish red to dusky brownish red forms more than 50% of the soil mass
Soil fabric	Voskelpic	Skelsepic followed by kelvoscepic	Skelsepic insepic and sepic	Skelsepic and insepic
Skeleton	Fine sand to silt size subangular and low relief quartz embedded in the dense plasma iron coatings in the centre and periphery of coarse and fine sand size quartz grains observed	Silt sized subangular to angular quartz embedded in comparatively less dense plasma less fractured low relief concretionary lateritic nodules > 2 mm size present with iron depositions exceeding 70% few silt size laterite fragments also present	Bigger sized quartz fractured and weathered repeatedly translocated clay fine clay and ferri argillan through the fissures to lower layers seen few opaque skeleton- ilmenite present	Bigger more than coarse sand sized subangular and subrounded quartz very few opaque minerals ilmenite observed at pockets
RDP	Plasmic	Grani plasmic followed by plasmi granic	Granic followed by grani plasmic	Plasmi granic
NRDP	Plasmic and porphyric	Granic plasmic and porphyric	Grani plasmic	Plasmi granic
Coarse/ finer fraction	Coarser	Coarser	Effectively coarser	Effectively finer
Voids	Highly porous channel and chamber shaped bigger voids	Channel and chamber shaped followed by ortho vughs	Vughs very few metavughs	Though the NRDP is plasmic the layer is rich in vughs Channel and chamber shaped surrounded by inner marginal ferran
Humus	Highly decomposed well aggregated dense dark reddish brown	Absent though present are leached	Absent	Absent
Chlamydomorphic coatings	Present	Absent	Absent	Absent
Litho relics	Absent	High relief dense wavy margin subrounded more than coarse sand size lateritic nodules less than medium silt sized lateritic fragments	Absent	Absent

Table 15 4 (contd)

Profile No	4	Eucalyptus plantation		
Horizon No	1	2	3	4
Cutans	Organan and ferri organan surrounding fine sand-sized quartz grains skeletons are seen embedded in the dense plasmified cutanic materials	Ferran argillan and rarely ferri argillan	Ferran	Clay pluggs papules stained with iron present in channels surrounding the bigger skeleton
Special observation	Dense reddish brown p s a o o e voids and skeleton	More dense reddish brown to yellowish red plasma less fractured quartz fine silt sized ilmenite few lateritic nodules of sizes more than coarse sand and less than medium silt	Highly fractured bigger quartz with re eated v trans located cutanic materials in the fissures	The horizon rich in ferran cutanic materials voids and bigger quartz grains The voids are with iron stained clay pluggs and papules

Table 15 5 Micromorphology of evergreen forest profile

Profile No 5	Evergreen forest		
Horizon No	1	2	3
Plasma	Dark reddish brown in colour aggregated iron coated forms about 50% of the soil mass	Yellowish red to dark reddish brown dense plasma presents as isolated patches forms major portion of the soil mass	Absent a rock in the initial stages of weathering more than 70% of the rock surface reveals physical weathering
Soil fabric	S e sepic insepic and isotic	Vosepic	sepic
Skeleton	Coarse sand to s s e medium to low relief subangular to subrounded quartz medium to fine silt sized element (%) and few sillimanite as other skeletons	Few present subangular subrounded and rounded low relief quartz fe fractured quartz are also present in the lithorelics	Rock pieces and quartz
RDP	Gran plasmic	Plasm-granic	granic
NRDP	Granic plasmic to porphyric	lasm granic	a anic
Coarser/ finer fraction	Coarser	Coarser	Coarser
Voids	Porous planar and packing rarely channel shaped	Ortho and metavughs channel and chamber shaped orientation of plasma gives a spongy appearance to the soil fabric	Channel and chamber shaped
Humus	Present as well decomposed plasmified aggregates with faint margins iron oxide glaebules are present as regions of concentration	Present in combination with iron as shining ferri organan aggregates one peculiar feature noticed is the presence of subangular and subrounded and less than silt sized quartz particles in the aggregates	Absent
Chlamydomorphic coatings	Generally absent but very few present	Absent	Absent

(contd)

Table 15 5 (contd)

Profile No 5	Evergreen forest		
Horizon No	1	2	3
Litho relics	Fine sand-sized subrounded and very few	More than coarse sand size dark dusky brown to opaque high relief subangular to sub-rounded present shiny lateritic nodules with sharp margin silt size subangular and sub-rounded quartz at different stages of weathering	Absent
Cutans	Ferri organan organa few ferran and very few ferri argillan ($< 1\%$) present	Ferri-organan few ferran and goethans and very few ferriargillans present	Ferran goethan and rarely ferri-argillan found as filled clusions in the fissures of physically weathered parent rocks and in the margins of voids
Special observation	Plasma not weel oriented and not well aggregated specific types of voids are not observable	Ferri-organan aggregates present as isolated dense patches quartz within giving a spongy appearance to the soil mass transported ferri organan cutanic materials are seen deposited or accumulated closer to the parent rock as dense well aggregated mass giving voskelpic to masepic plasmic fabric	Parent rock in the initial stages of weathering (Plate 46) indicated initial signs of laterisation here as a general principle physical weathering preceds the chemical weathering which is also active by enrichment of dissolved ferran and goethan repeatedly in the fissures of fractured parent rock and inner margin of voids They are formed by a significantly slow process in a reacting medium of fine and highly compact soil-a plinthite horizon or rock in the initial stages of weathering

Table 15 6 Micromorphology of tea plantation profile

Profile No 6	Tea plantation		
Horizon No	1	2	3
Plasma	Light grey to dusky brown/ blackish brown few	Dusky brown to yellowish brown in colour dense few organan coated forms about 60% of the soil mass	Yellowish red to yellowish brown comparatively less dense argillaceous forms major portion of the soil mass
Soil fabric	Skelsepic	Skelsepic skelvosepic and insepic	Plasmic fabric is insepic
Skeleton	Silt to coarse sand sized less fractured and medium to lower size quartz present rare sillimanite and very few ilmenite also present dominantly subangular and rarely subrounded	Fine sand to silt sized subangular and subrounded quartz quartz not weathered very few opaque minerals present Hematite goethite and ilmenite (fine sized) present embedded in the plasmic organic matter	Fine sand sized quartz subangular very few and black opaques also present
RDP	Granic	Plasmi granic	Plasmi-granic
NRDP	Granic	Plasmi-granic	Plasmi granic at places porphyric
Coarse/ fine fraction	Coarser	Coarser	Fine
Voids	Vughs and metavughs planer and packing	Vughs and metavughs channels and chambers present at the lower boundary of the horizon	Channels and chambers followed by bigger vughs
Humus	Granular and crumby well aggregated dense and subrounded to rounded humus with sharp margin present more on the skeleton and less below the skeleton dusky brown to blackish brown in colour	Dusky brown to brownish red humus present as spherical bodies and as finemat	Present as ferri organan
Chlamydomorphic coatings	Signs of chlamydomorphic coatings NRDP in few places surrounding bigger skeleton forms about 5% only	Present but incomplete	Absent

(contd)

Table 15 6 (contd)

Profile No 6	Tea plantation		
Horizon No	1	2	3
Lithorelics	Absent	Absent	Lateritic nodules with few quartz skeleton and more iron coating present
Cutans	Organan and rarely ferri-organan	Signs of formation of ferri-argillan on the voids and on margins of silt sized quartz grains formation of ferri argillan in the initial stage	Argillan ferran ferri argillan and the least ferri-organan In the same horizon two totally different pedogenesis are in operation
Special observation	Voids are not clearly observable as there is lack of orientation of packing blackish-brown to dusky brown organic-matter few opaque minerals present	The yellowish brown faint margin of the well granulated dense plasma indicates current and active translocation of ferran-organan cutanic materials formation of ferri-argillan in the initial stage skeleton forms less than 50% of the soil mass presence of numerous fine silt sized hematite and limonite particles is another peculiarity orientation of the plasma is flaked	Though there are signs of active formation of ferri-argillan it is seen blocked by the presence of dense argillaceous plasmic material with comparatively less iron Thin section reveals the diagenesis - argillation and ferri-argillation as inseparable biozones abrupt and wavy boundary is clear paralithic contact is less parent rock below is highly weathered

Table 15 7 Micromorphology of shola forest profile

Profile No 7	Shola forest				
Horizon No	1	2	3	4	5
Plasma	Grey to brownish yellow in colour occupies very small portion of the soil mass	Greyish brown to yellow brown in colour forms about 70% of the soil mass	Yellowish grey to grey in colour forms a small portion of the soil mass	Forms small portion of the soil mass	Few or absent
Soil farbic	Asepic insepic and [illegible]	Plasmic and voskelsepic	Asepic to skelsepic	Asepic and skelvosepic	Asepic
RDP	Grani-plasmic	Plasmi-granic	Grani-plasmic	Grani-plasmic	Granic to grani-plasmic
NRDP	Grani-plasmic and rarely porphyric	Plasmic granic to porphyric	Grani plasmic	Grani-plasmic	Granic to gran [illegible]
Coarser/ finer fraction	Coarser	Coarser	Coarser	Coarser	Coarser
Skeleton	Few fine to coarse sand-sized subangular and subrounded quartz less than fine sand-sized hematite present	A few coarse to fine sand size subangular fractured and ferri-organan coated quartz and the remaining ones are less than silt-sized and subrounded to rounded	Coarse sand sized subangular and subrounded fractured quartz and highly coated with iron and ferri organan are present	Quartz under various stage of physical weathering exhibiting lines points and plane of cleavages	Quartz and parent rock composite pieces angular and coated with iron marginally
Voids	Highly porous specific types of voids not observable channel and chamber shaped voids are present in plasma rich region	Channel and chamber shaped voids form about 50% of void space and the rest composed of ortho and metavughs	Highly porous no specific types of voids not observable due to lack of orientation of plasmic material and pedological features	Ortho and metavughs	Absent
Humus	Dark brown to dusky reddish brown iron coated and medium to high relief ferri organan with irregular margin humus aggregates present not in a well oriented form	Leached well decomposed and plasmified ferriorganan The organic matter in the form of aggregate is comparatively less	Highly iron coated and well aggregated compared to the upper layers ferri organan presents as aggregates of flaked orientation	Absent	Absent

(contd)

Table 15 8 Micromorphology of acacia plantation profile

Profile No 8	Acacia plantation		
Horizon No	1	2	3
Plasma	Grey to yellowish grey in colour occupies about 50% of the soil mass	Grey to yellowish brown in colour forms small portion of the soil mass	Yellowish brown to dusky reddish brown plasmified organan forms major portion of the soil mass
Soil fabric	Skelsepic	Asepic insepic and so ic	Voskelsepic to osepic
RDP	Grani-plasmic	Plasmi-granic	Plasmic to plasmi-granic
NRDP	Grani-plasmic to porphyric	plasmi-granic	Plasmic to porphyric
Coarse / finer fraction	Coarser	Finer	Finer
Skeleton	Fine to coarse sand-sized hetched subangular and fractured quartz fissures and hetched areas of the skeletons are filled with dusky reddish brown ferri-organan-cutans	Few silt to fine sand-sized fractured and subangular quartz present	Less than fine sand-sized subangular and subrounded quartz of low relief few opaques hematite goethite and limonite also present
Voids	Porous channel and vughs	No specific type is observable due to lack of orientation of plasmic and skeleton materials which are lesser in content	Channel and chamber shaped
Humus	Iron rich ferri-organan surrounding the skeleton, their fissures and hetched areas and surrounding the channels and vughs	Fine silt-sized dusky reddish brown ferri-argillan aggregate present as plasmified humic materials	Absent
Chlamydomorphic coatings	Few present	Absent	Absent
Litho relics	Few fractured and hetched lateritic litho relic	Dusky reddish brown fractured subrounded with sharp margin, highly iron coated and quartz rich lateritic nodules present	Absent

(contd)

Table 15 8 (contd)

Profile No	Acacia plantation		
Horizon No	1	2	3
Cutans	Ferri-organan	Ferran and ferri-organan present surrounding the skeletons and as in-fillings of their fractures	Ferran ferri-organan very few ferri-argillan and translocated clay argillan- present surrounding the skeleton and voids
Special observation	Fine to coarse sand-sized fractured and hetched quartz lithorelics and thick ferri-organan humus present	Both skeleton and plasma materials form less portion of the soil mass quartz rich iron coated and fractured lateritic nodules present ferran and ferri-argillan form the main cutanic materials specific type of voids not observable	Ferri organan present as yellowish brown to dusky reddish brown platy aggregates well oriented channel and chamber shaped fine voids present skeletons are of low relief subangular and subrounded and less than silt-sized few black yellow and red opaques present

Soil fabric

Irrespective of the profile, the dominant soil fabric was skelvosepic followed by vosepic and argillasepic. Asepic fabric is a universal feature of the laterite layer or lower laterised layers.

Soil plasma

The soil plasma was predominantly dark reddish brown in colour even in soils under evergreen ecosystem. No specific characteristic influence was observed in the colour of the plasma by different vegetation except that in shola (plates 56 to 63) and tea (Plates 49 to 55) soils where the colour strength was comparatively lesser. A lesser plasma was the characteristic feature generally observed in the soil except evergreen (Plates 41 to 48) shola and tea soils which presented more plasma and less skeleton.

Skeleton

The soil skeleton consisted of angular to subangular, fractured or non-fractured quartz with low relief and biotite mica.

Related distribution pattern/Normal related distribution patter (RDP/NRDP)

The RDP of the soil was dominantly chlamydomorphic in the surface and porphyric and granic to grani-plasmic in the subsurface. Even in soil under evergreen, shola and tea granic and grani-plasmic RDP was observed. The NRDP

Plate 18 The yellowish brown, dark yellowish brown and light grey portions indicate plasma which consists mainly of ferri-organan and rarely ferri-argillan. Silvosepic plasmic fabric, voids plannar and packing. The blackish brown area (right) is a lateritic nodule.
Deciduous forest 1st layer (0-4 cm) thin section in plain light
Mgf x 25

Plate 19 Subangular and subrounded quartz grains (white spots) embedded in dense plasma. Hematite, magnetite and few feldspars are also seen present. Note the enriched quartzitic subangular more than coarse sand size lateritic nodule (right).
The above frame (Plate 18) under Crossed Nicols Mgf x 25

Plate 20 The yellowish brown and dark brown argillan and ferri-argillan occupying major portion is the plasma. Vosepic to skelsepic plasmic fabric.
Deciduous forest 2nd layer (4-16 cm) thin section in plain light
Mgf x 25

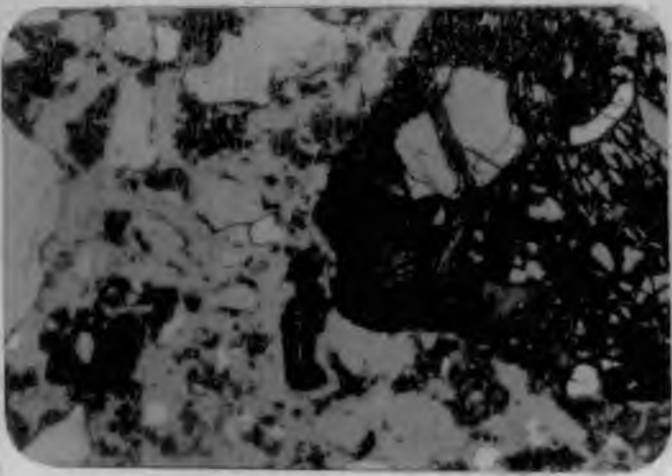
Plate 21 Note the vanishing boundaries of the plasma indicating translocation of clay and cutanic materials. Subrounded to rounded, less than fine sand size, low relief quartz grains present. Few opaques are also present. The infilling of the fissures in large quartz grain (top central) is ferriorganan.
The same frame (Plate 20) under Crossed Nicols Mgf x 25

Plate 22 The strong brown colour occupying major portion is the plasma which consist of ferran and ferriargillan. Note the presence of channel and chamber shaped voids. Few small lateritic litho relics are also seen present.
Deciduous forest 3rd layer (16-57 cm) thin section in plain light
Mgf x 5

Plate 23 Yellow brown plasma occupies the major portion. Note the subangular high relief lateritic litho relics and kaolin filled channels. Highly fractured quartzitic nodules (right), silt size quartz scattered in the dense plasma.
The above frame (Plate 22) under crossed Nicols Mgf x 25

Plate 24 The reddish yellow portion is the plasma which consists of ferriargillan. Subangular iron rich fractured quartzitic nodules are more than coarse sand size. Note the presence of pure kaolin as infilling in fractures and voids.
Deciduous forest [illegible] layer (57-[illegible]20 cm) thin section in plain light
Mgf x 2

18



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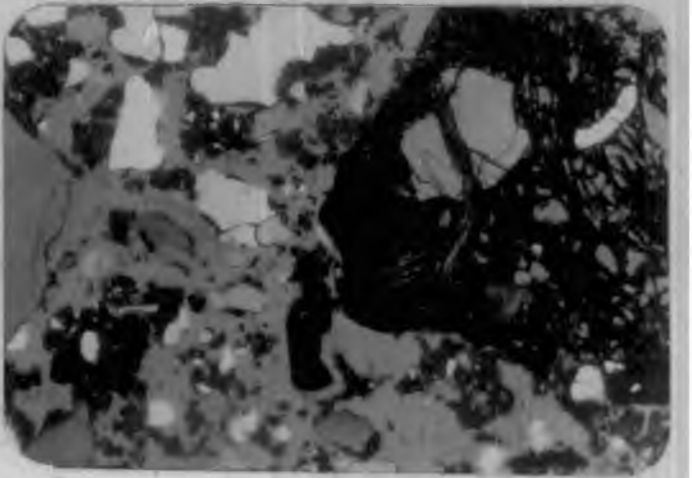

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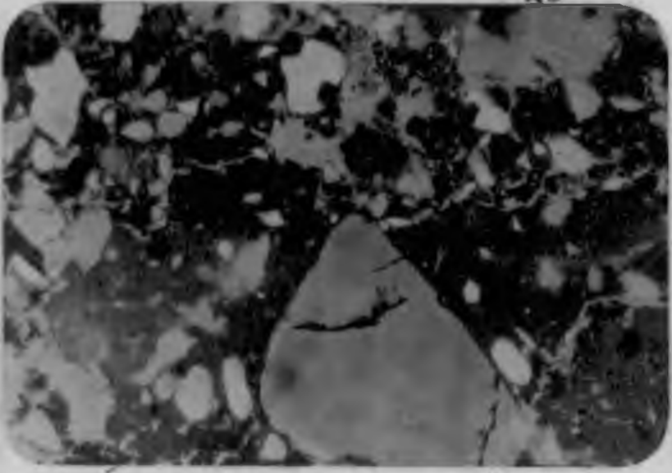

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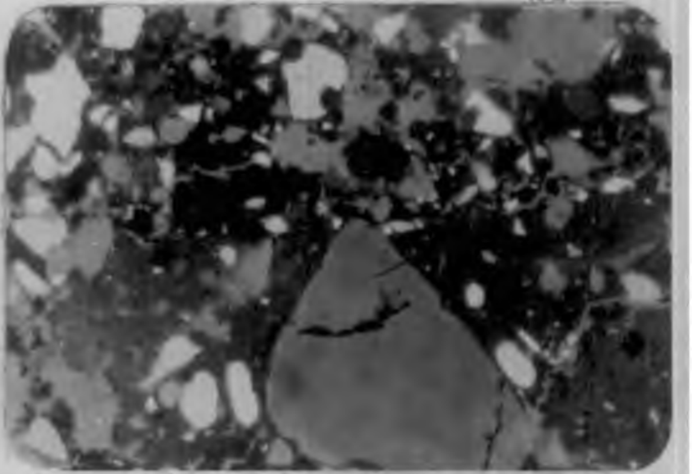

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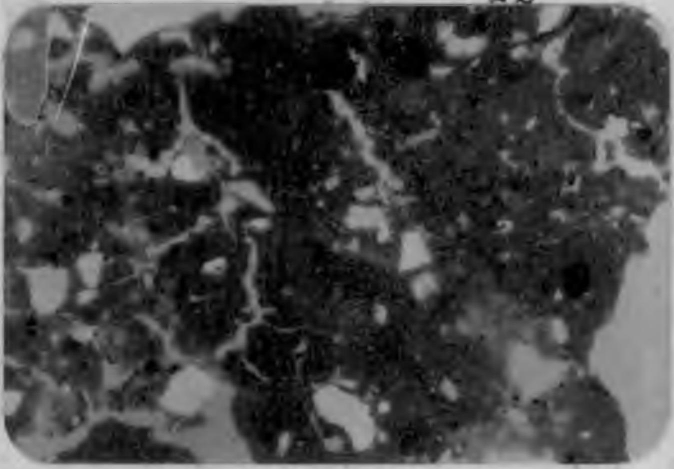

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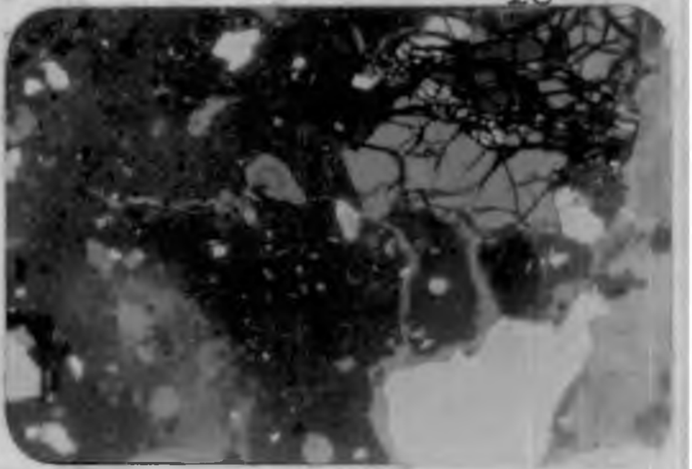

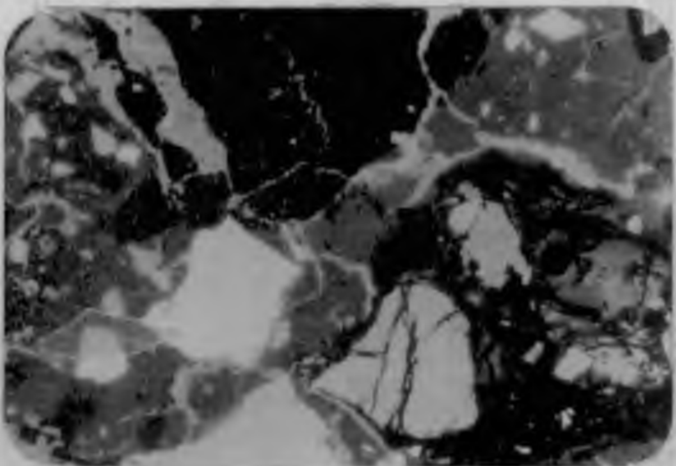

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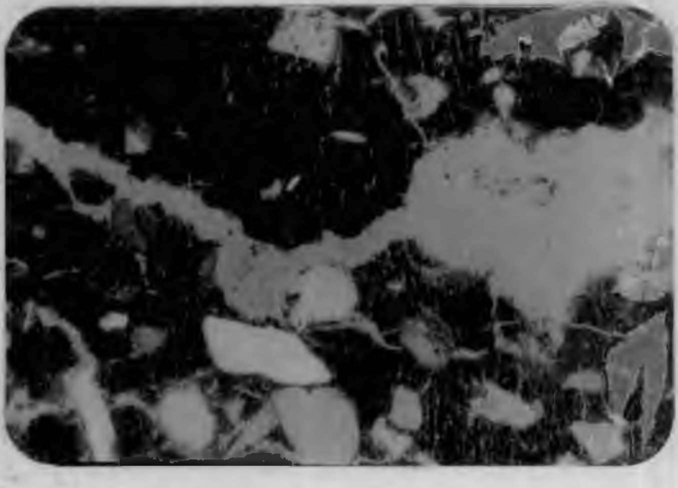
Plate 25 bro[illegible] i[illegible]y [illegible] l[illegible]w po[illegible]t [illegible] the plasma which is well aggregated [illegible]ot [illegible] b[illegible] [illegible]ped voids (Central) and very fine channel [illegible] lo relief less than fine sand size sub-a[illegible] u[illegible]r [illegible] ur[illegible]n[illegible]d quartz grains Few magnetite hematite a[illegible] f[illegible]l[illegible] [illegible] [illegible] present
C[illegible] t[illegible] [illegible]t l[illegible]y (0-19 cm) thin section in plain light
Mgf

Plate 26 T[illegible] [illegible] l[illegible] [illegible]nse plasma i[illegible] well [illegible]r[illegible]g[illegible]ted [illegible] f[illegible]r[illegible] [illegible] ll [illegible] d[illegible] [illegible] t[illegible]ty Iron enriched subangular to [illegible] [illegible]a[illegible]u[illegible]l[illegible]t[illegible] t[illegible] nodules (right) Few opaques and low relief of quartz g[illegible] [illegible] also present
C[illegible] [illegible]l[illegible] t[illegible]at[illegible] [illegible] [illegible]r (19-46 cm) thin section in plain light
Mgf

Plate 27 Iron enriched zone of lateritic nodules (right) are dominantly ferr[illegible] [illegible] g[illegible] t[illegible] a[illegible] T[illegible] faint margins of the plasmic aggregate indicate t[illegible] translocation of cutanic materials Voids are mainly c[illegible]a[illegible]el[illegible] [illegible]d[illegible] c[illegible] [illegible]ber[illegible] h[illegible]ed, following planar and packing
T[illegible]e[illegible] [illegible] f[illegible] (Plate 26) under Crossed Nicols Mgf x 5

Plate 28 Dusky brown plasma [illegible] fe[illegible] more than coarse sand size high relief fractured [illegible] t[illegible] grain (Upper right) with translocated ferran and argill[illegible] [illegible]i[illegible] t[illegible] f[illegible] [illegible]s Voids [illegible]r[illegible] [illegible] mainly channel [illegible] d[illegible] c[illegible]amb[illegible]r[illegible] s[illegible] [illegible]ed Few le[illegible] [illegible]t[illegible] [illegible] [illegible]lt[illegible] i[illegible]e opaques are also [illegible]ee[illegible] present
Cashew plantat[illegible] - 3rd layer (46-120 cm) thin section in plane light
[illegible]gf



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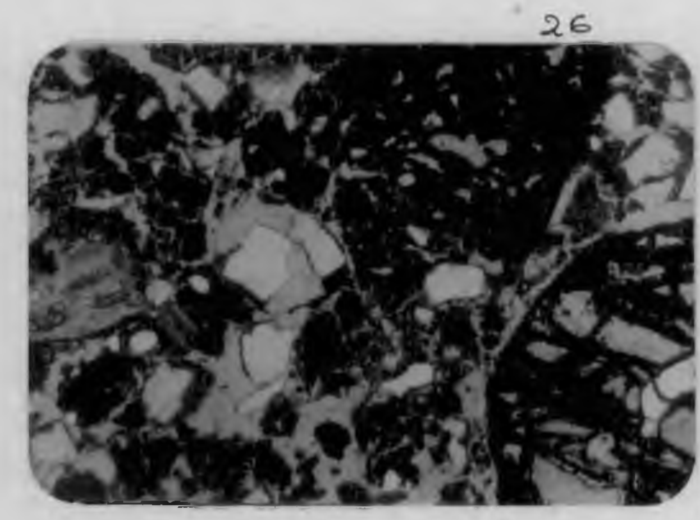

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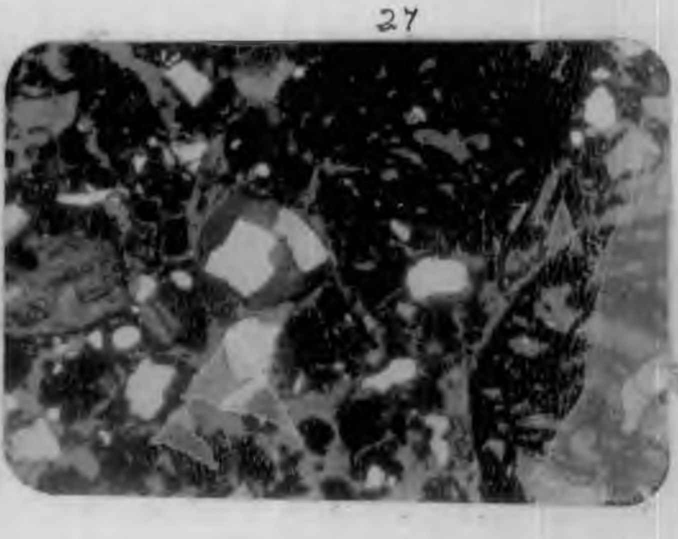

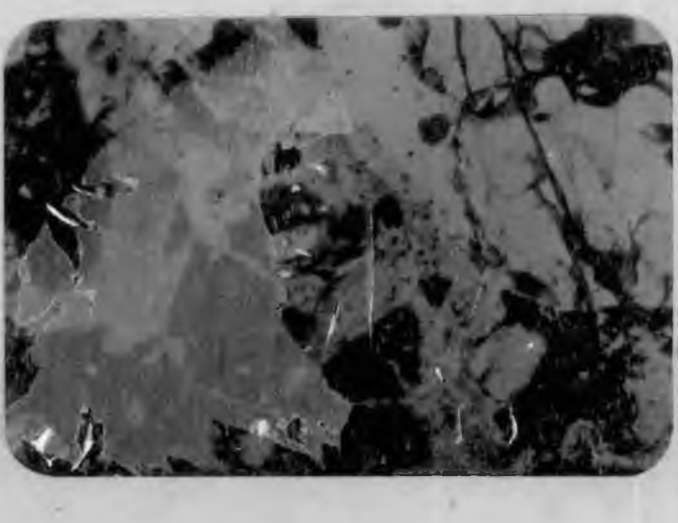

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Plate 29 The very [illegible] reddish black dense plasma consists of ferric [illegible] plasmic fabric followed by [illegible] porphyric [illegible] tending to become chlamydomorphic [illegible] ferri-argillans also present.

Semi-evergreen forest 1st layer (0-10 cm) thin section in plain light [illegible] 25

Plate 30 Note the [illegible] ferri-argillans, limonite and [illegible] at the [illegible] and the chlamydomorphic bridging of the [illegible] organ[illegible]. Quartz grains are coarse [illegible] size, angular to [illegible] low relief [illegible]

The [illegible] (Plate [illegible]) under crossed Nicols Mgf. x25

Plate 31 See the [illegible] plasma. Granic [illegible] and chlamydomorphic [illegible] Orthovughs and metavughs and planar voids [illegible] interconnected voids

Semi-evergreen [illegible] layer (10-23cm) thin section in plain light [illegible]

Plate 32 [illegible] fine sand size, non-[illegible] quartz grain [illegible] ferri-organ[illegible]

The above [illegible] (Plate 31) under Crossed Nicols Mgf [illegible]

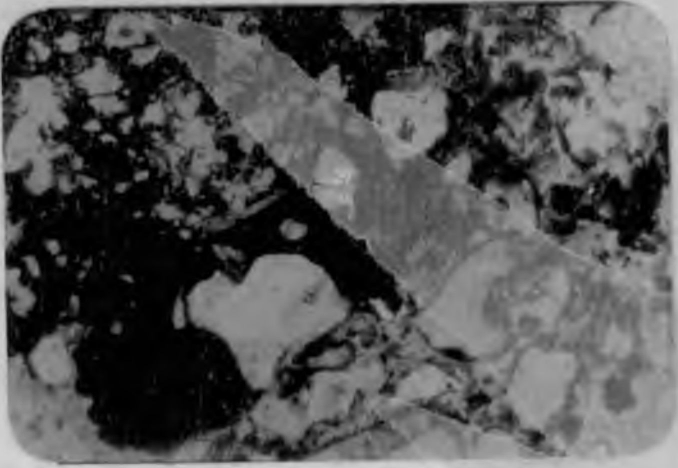
Plate 33 [illegible] aggregate with ferra[illegible], [illegible] increasing order in [illegible] (left). Note the cleavage [illegible] (right) is [illegible] on [illegible] Semi-evergreen forest 3rd layer [illegible] plain light, Mgf x 25

Plate 34 The dark [illegible] [illegible]ated with iron by local redistribution from the light areas. The higher [illegible] (white areas) in the parts that [illegible] indicate that these parts have been coll[illegible]. The yellow parts are crystalline goethite which form a [illegible] net work especially in the walls of channels and nearby areas. The dark streak through the centre is a former channel filled with fine grained hematite. The white sports are quartz grains.

Semi-evergreen forest 4th layer (42-120 cm) thin section [illegible] Mgf x 25

Plate 35 Subangular [illegible] quartz rich [illegible] iron rich [illegible] (upper and lower right) [illegible] bigger quartz grains and voids [illegible]. Yellow margins of the [illegible]. Major portion is occupied by [illegible]

Semi-evergreen forest 4th layer (42-120 cm) on other [illegible] plain light, Mgf. x 63.



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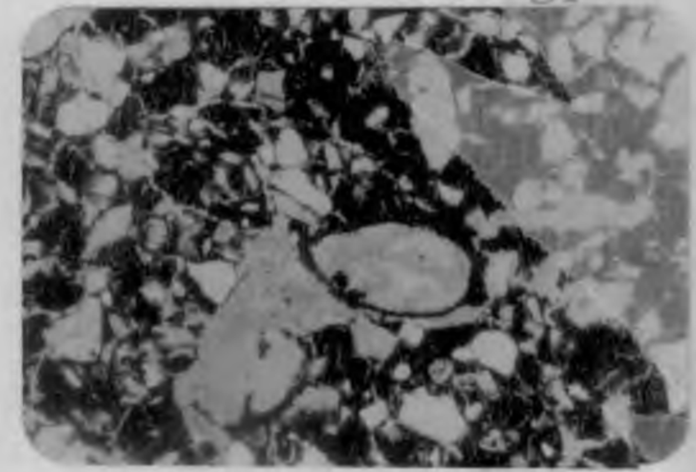

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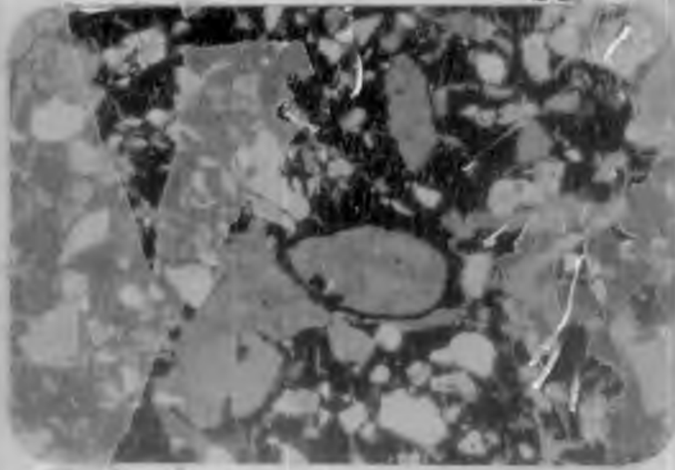

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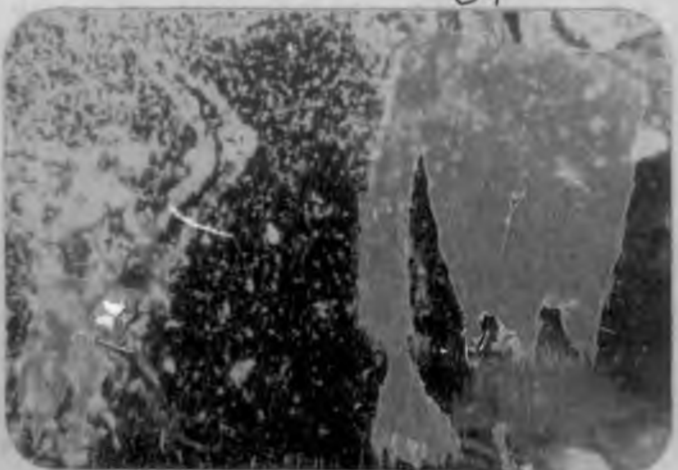

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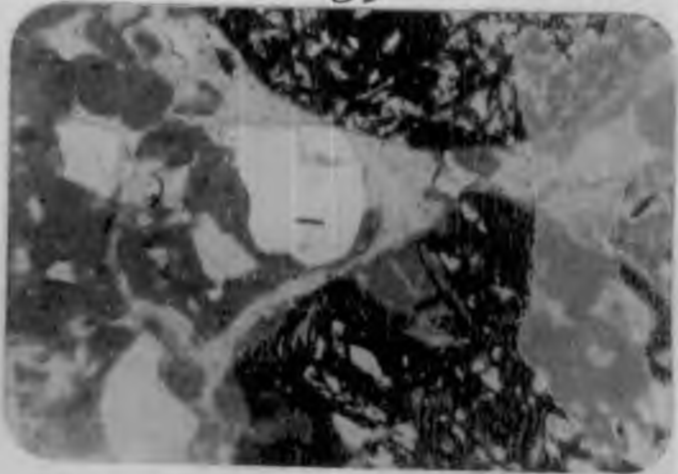

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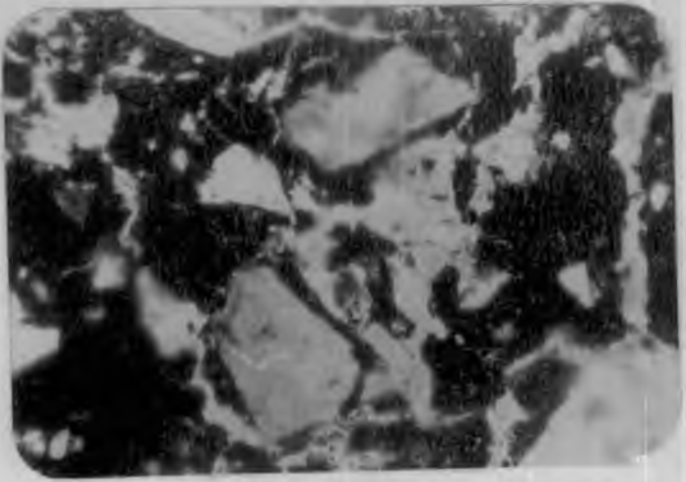
Plate 36 The dark redd[illegible] portion consist of iron coated plas[illegible] [illegible] bigger channel and chamber shaped voids. The sub[illegible]gular, low relief white spots are the quartz grains. Fine sand size quartz grains are seen coated with iron oxide in the centre and periphery.
Eucalyptus plantation 1st layer (0-11 cm) thin section in plain light Mgf. x 6

Plate 37 The yellow [illegible] moderately dense plasma. Skelvo[illegible] [illegible] irregular streaks [illegible] channel [illegible] chamber [illegible] Vughs are also present. Iron enriched su[illegible] lateritic nodules (upper left). The faint [illegible] translocation of clay and clay [illegible]
Eucalyptus plantation [illegible] layer (11-26 cm) thin section in plain light [illegible]

Plate 38 [illegible] quartz grain with [illegible] the fissures
Eucalyptus plantation 3rd layer (26-57 cm) thin section in plain light Mgf. x

Plate 39 Clay [illegible] with iron oxides are present in channels surrounding the bigger quartz sekeleton. Litho relics absent
Eucalyptus plantation 4th layer (57-130 cm) thin section in plain light Mgf. x [illegible]5

Plate 40 Weathering of bigger iron quartz grains with cleavages stained with ferri-argillans. Vughs, channels and chamber voids. Few ilmenites are observed at pockets.
Eucalyptus plantation 4th layer (57-130 cm) on other field of observation of the thin section in plain light Mgf. x 25



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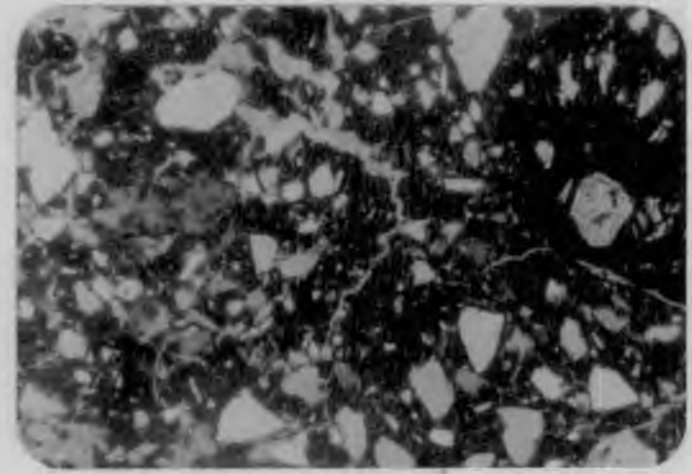

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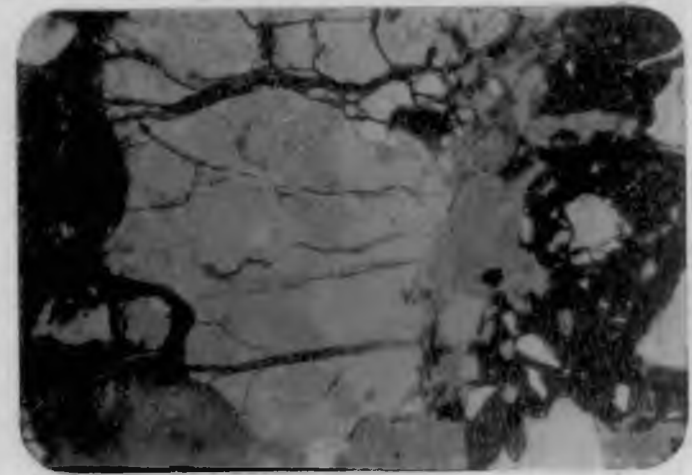

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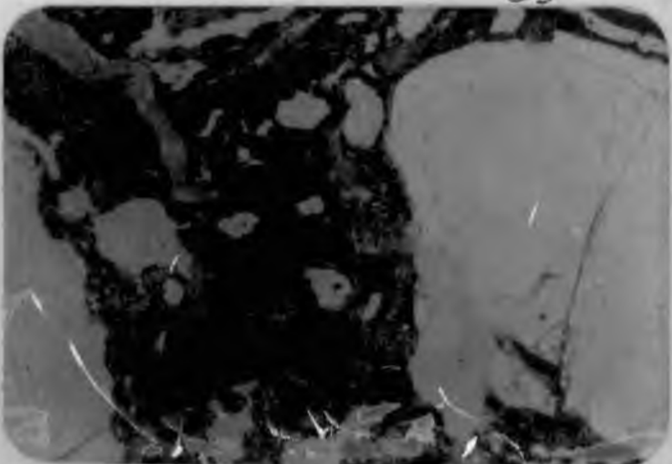

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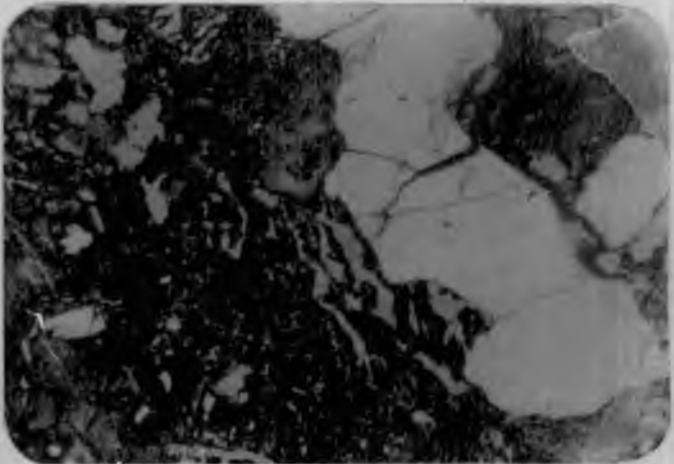

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Plate 41

Dark reddish brown aggregated plasma t ir n c at ngs surrounding the skeleton. The plasmic fabric is skelsepic insepic and isotic. Porous in structure. Planar d ck n voids d rarely channel shaped. Very f w ll u ro l t relic e e t

Evergreen forest 1st layer (0 c t n section in plain light gf x 25

Plate 42

Note the presence of coarse to f e d s ze uartz medium to fine silt sized ilmenite and few lli te unus present as well decomposed plasmified aggregates. Iron oxide globules present as regions of c ncent t

The above frame (Plate 41) under Crossed c ls gf x 25

Plate 43

Yellowish red to dark reddish br n dense plasma. Vosepic plasmic fabric. Ortho and meta vug s c an el and chamber shaped voids. The orientation of the plasma gives a spongy appearance to the soil fabric. Small silt sized subangular and subrounded quartz grains are seen fixed on the ferr orga an agg eq tes

Evergreen forest 2nd layer (21 c) t i sect n plain lig t gf x 2

Plate 44

Few b ul o b ou l u q re t some quartz grains a e fractured C rs s s ze du ky brown subangular to subrounded h g rel ef l ter t c nodules with sharp marg n

The above ob vat n (late 43) u d o d N l gf

Plate 45

Illustrate t e tra s t on stag b t ee he nd nd 3rd horizons. Paret rocks in the in tial t q a r g (lo r) T n orted ferri-organan cut mater s seen accu l ted o er the parent material (upp r)

Evergreen forest tr sitio zo e b tw e d an 3rd orizons Thin section i plain light gf x

Plate 46

The light areas of the crystal aggr g tes (lo er r ght) are gibbsite formed upo weat f aol n T e w te s ot a e quartz grains. The few fra u rtz cate d ff ent st g s of weat er ng. The fissur s of t t r ng qu rtz (central) are seen filled up by iron or ferr - rga an

The above observation (plate 45) er Crossed c gf x

Plate 47

eat r g of ar t r cks er ic l at er g is preceeding the c emical weathering whic s lso active by enr chment of dissolved ferran nd goethan i t f ss of y ally weat e ed parent rocks nd t ir marg s

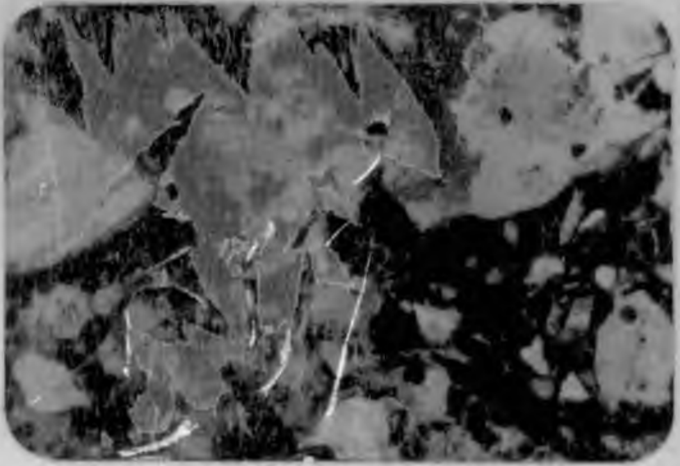
Evergreen forest 3rd layer (51 120 c) t n section plain light Mgf x 25

Plate 48

The yellows ade indicates t e prese ce d ssol d goethite. The ferran forms a continuous network esp c lly on t e walls of the c annels. The dark areas of t e c ferr argillan

The above obse vatio (plate 47) C N ls, gf x 2

41



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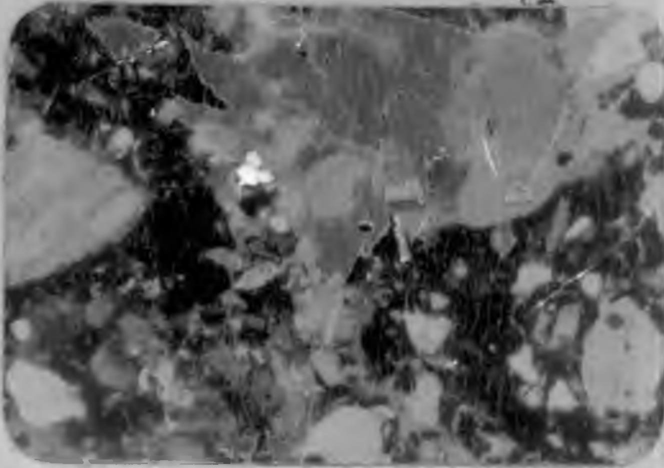

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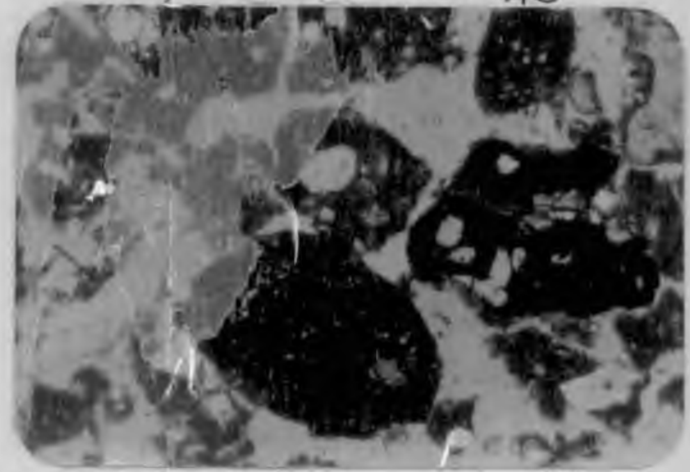

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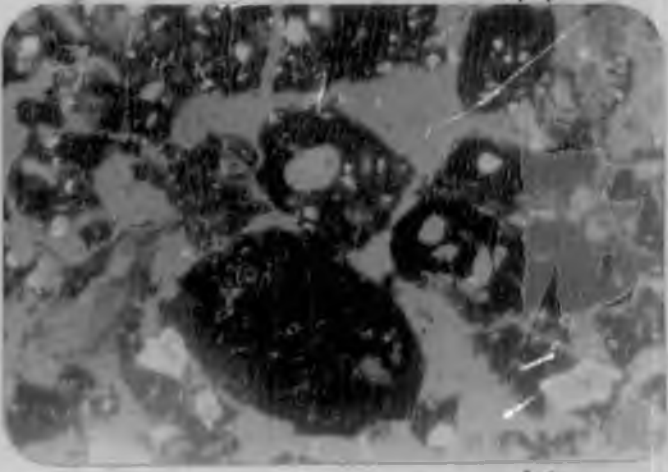

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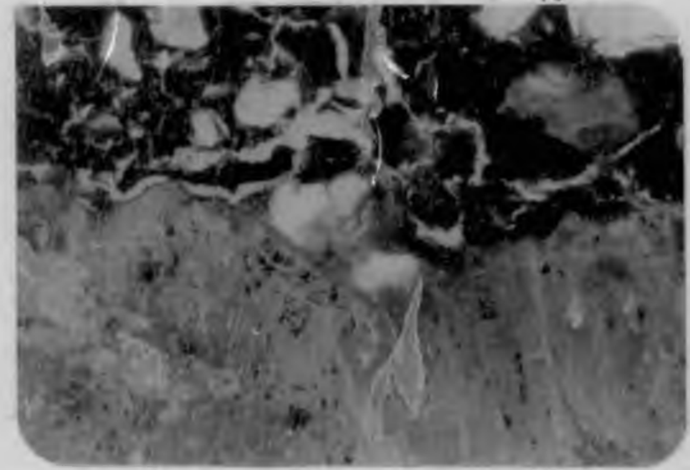

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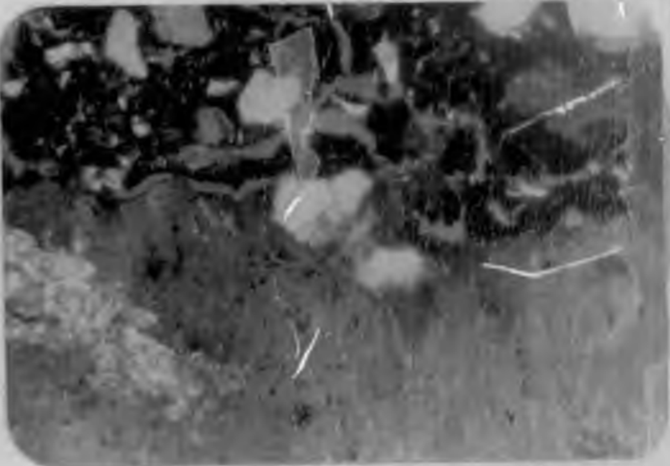

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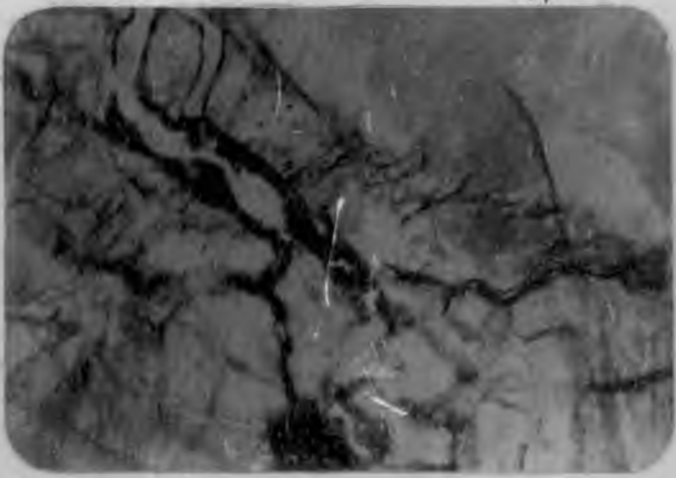

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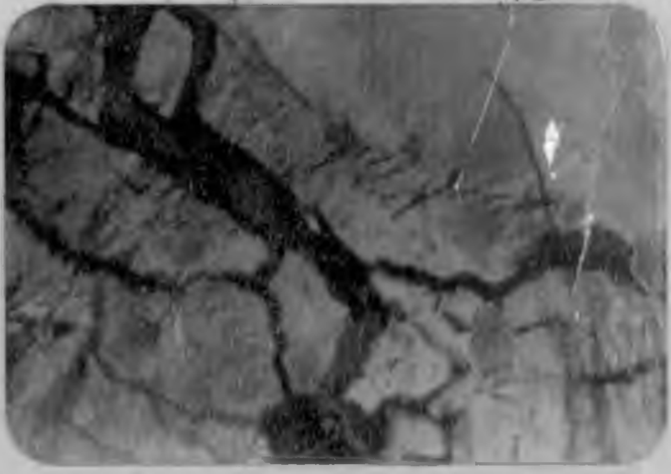

Plate 49	The blackish bro n area is the plasma which consists of organan The soil fabric is skelvosepic well aggregated u u wit s rp m rg n Voi s e u] d meta v s pl ar a d packing I e v id a e not clearly observable due to the lack of orientation Tea plantation 1st layer (0- 4) thin section in plain light Mgf x 25
Plate 50	Silt to coarse sand size medium to low relief quartz grains few sillimanite and ilmenite are also seen present The above observation (plate 49) under Crossed Nicols Mgf x 25
Plate 51	The dusky brown a t e y ll i wn portions indicate plasma w c i ense a d ferri- rg a coated The soil fabric is skelsepic skelvosepic nd isepic Voids are vughs and metavughs Channel and chamber shaped voids are seen at the lower portion u u p es t as spheric l bodie Tea plantation 2 d layer (1 -30 c) thin section in plain light Mgf x 25
Plate 52	Fine sa to silt size subangular to subrounded less weathered quartz grain Few hematite goethite and limonite (fine sized) are also present embedded in the plasmified organic matter The above observation (plate 51) under Crossed Nicols, Mgf x 25
Plate 53	The yellowish red to yellowish brown portion is the plasma which is less dense and argillaceous Plasmic fabric is insepic lateritic nodule with few quartz skeletons and with more iron coating (lower left) oids are channel and chambers followed by bigger vughs Tea plantation 3rd layer (30-130 cm) thin section in plain light Mgf x 25
Plate 54	Fine sand size few quartz grains re present as ite spots V ry few ed an black u s e l ee resent The above observation (plate 53) under Crossed Nicols Mgf x 25
Plate 55	The active formation of ferr arg llan is seen blocked by the presence f dense argillaceous plasmic materials with comparatively less iron brupt an wavy boundary is clear Paralithic contact is less and the parent rock below is highly weathered Tea plantation 3rd layer a th r view of the thin section under Crossed Nicols Mgf x 25

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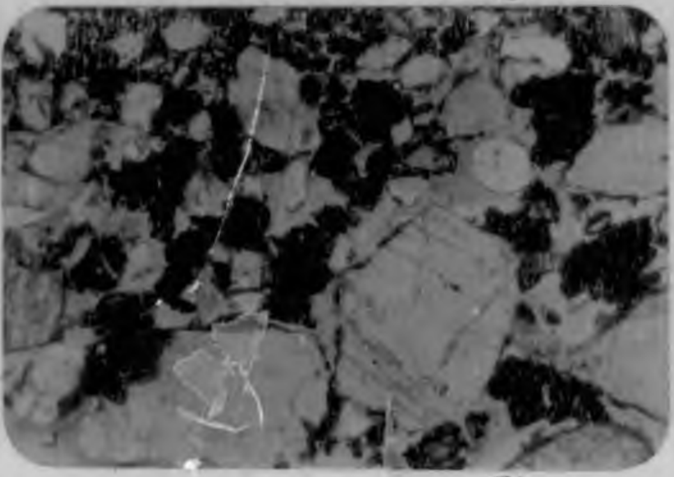

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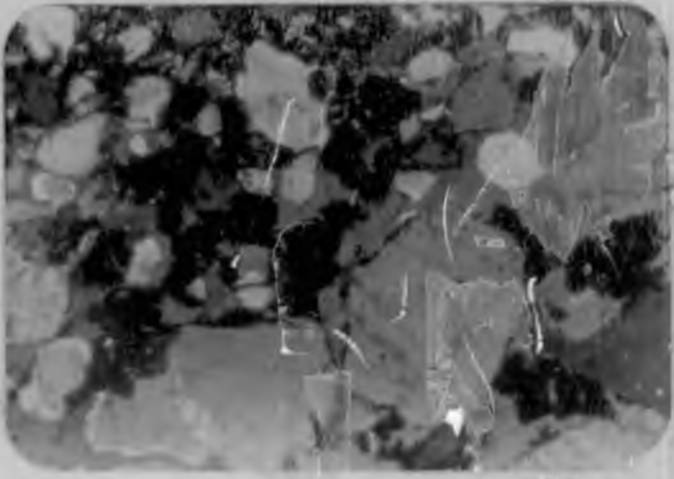

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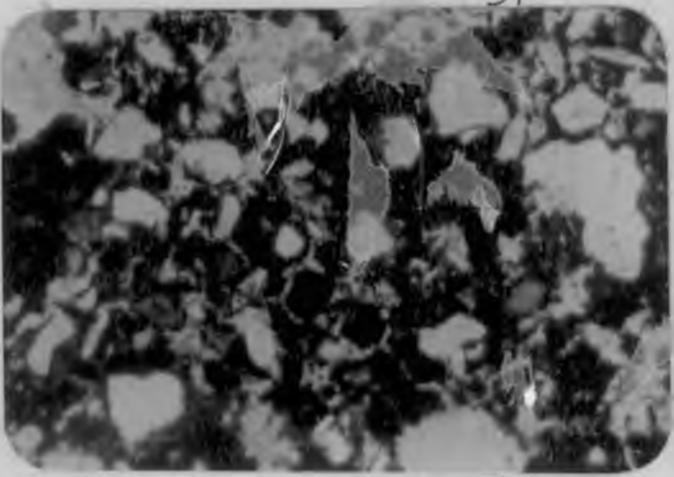

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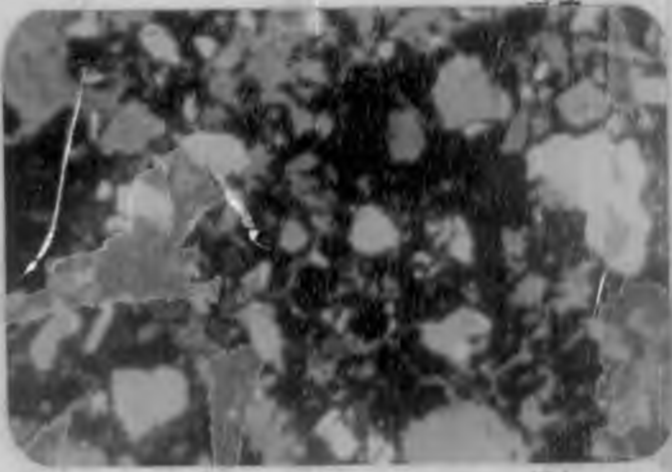

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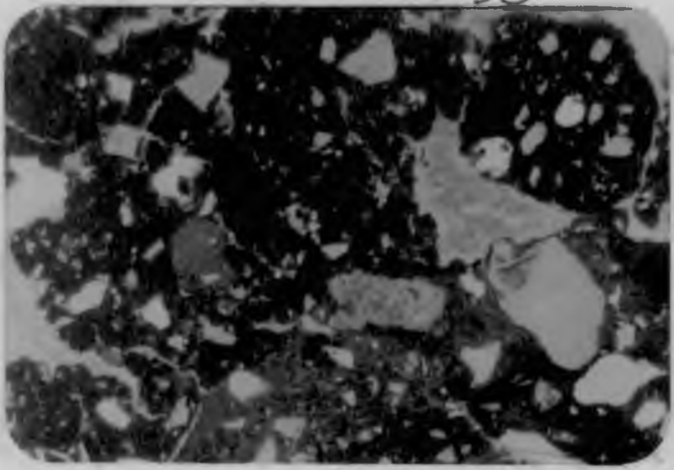

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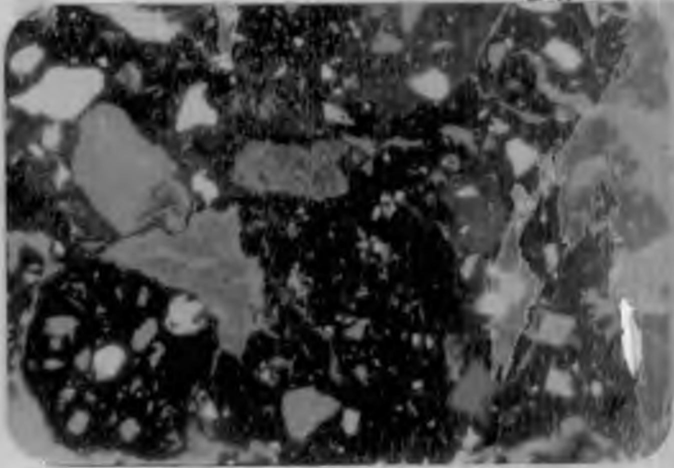

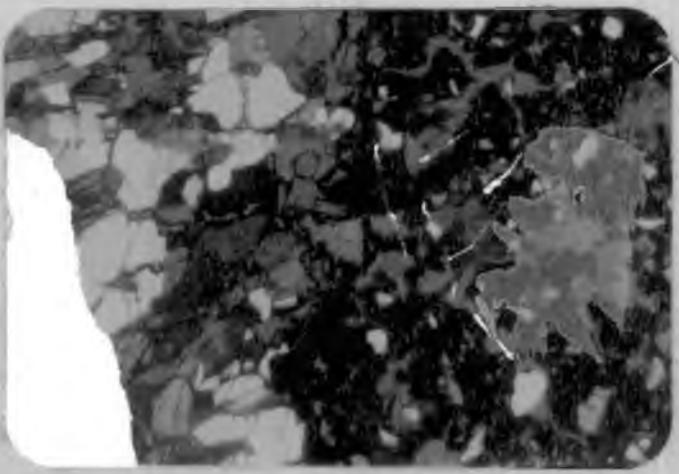

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Plate 6

Brownish yellow portion indicates plasma il farbic is asepic insepic and isotic Highly porous and specific types of voids are not observable The dark brown to d sky brown with irregular marg s t e ron coated fer o a G ni lasmic and rarely porphyric DP Channel and chamber ed voids in plasma rich region Few fine to coarse sand size subangular and subrounded quartz grains and less than fi e s ze tite are present Iron coated lateritic litho relic are also seen present

Shola forest 1st layer (0-12 cm) thin section in plain light Mgf x 25

Plate 57

The greyish brown to yellowish brown portion is the plasma which is well decomposed and leached ferri organan The soil fabric is plasmic and voskel epic Plasmi-granic to porphyric NRDP Voids are channel and chamber shaped with irregular margin Few coarse to fine sand size subangular fractured ferri organan coated and less than silt size quartz grains present

Shola forest 2nd layer (12 27 cm) thin section in plain light Mgf x 25

Plate 58

The yellowish grey to gray portion indicates plasma The soil fabric is asepic to skelsepic Graniplasmic NRDP Highly porous No specific voids are evident due to lack of orientation of plasmic material The dark brown portion with irregular margin is the well aggregated highly iron coated humus

Shola forest 3rd layer (27-56 cm) thin section in plain light Mgf x 25

Plate 59

Coarse sand size subangular and subrounded quartz highly coated with iron and ferri-organan present

The above observation (plate 58) under Crossed Nicols, Mgf x 25

Plate 60

Plasma forms small portion of the soil mass The soil fabric is asepic and skelvosepic Graniplasmic NFDP Quartz grains under different stages of physical weathering exhibit lines points and planes of cleavages Voids are ortho and metavughs

Shola forest 4th layer (56-67 cm) thin section in plain light Mgf x 63

Plate 61

The horizon is rich iron and is under different stages of active physico-chemical weathering Ferran and goethans are present as regions of concentration in the forms of webbs surrounding the vughs and skeletons

The above observation (plate 60) under Crossed Nicols, Mgf. x 63

Plate 62

The plasma is rarely present The soil fabric granic to grani-plasmic Voids are absent The parent rock seens under active physico-chemical weathering Ferran and few ferri argillans are seen surrounding the skeletons Compared to the upper this layer is with more iron e c ent

Shola forest th layer (6 40 c) thin section in plain light Mgf x 25

Plate 63

Note the angular quartz grains are t rock composit pieces marginally coated with iron

The above observation (plate 62) under Crossed Nicols, Mgf. x 25

Plate 64	The grey to yellowish grey portion is the plasma of the soil The soil fabric is skelse Grani lasn c to orphyric RDF The soil o u t c n els a d vughs richly iron impregnated h m s is seen surrounding the channels Acacia plantation 1st layer (0 - 24 c) thin section in plain light gf x 25
Plate 65	Note the fine to coarse sand size hetched subangular and fractured quartz grains The fissures and the hetched areas of the skeletons are seen filled with dusky reddish brown ferri o ganan Few fractured litho relics are also present The above observation (plate 64) under Crossed Nicols Mgf x 25
Plate 66	The grey to yellowish b ort soil plasma The soil fabric is asepic insep c a d otic lasm granic LP No specifi ty e f o b e v le Dusky redd brown (1 t d 1) fr ctu d subrounded wit sharp m rg i j ly ron co ted nd u rtz rich laeritic nodule Acacia plantation 2nd layer (24-79 cm) thin section in plain light, gf x 25
Plate 67	The yellowish brown to dusky bro n portion s lasmified organan T s l v el e c Plasmic to porphyric LP F an el c am er shaped voids Ferran ferr o g an v ry f w ferri argillan a tr nsloc e rg lla are ee p esent urrou d t e kelet s a Acacia plantation 3rd layer (79 20 cm) t n sect on n plain light Mgf x 25
Plate 68	e t e le t f l r sub ou ded lo relief t q F a s e at te goethite and l t e ferr a s dusky reddis rown laty agg eq te The above observatio (plate 67) under C os ed col Mgf x 25

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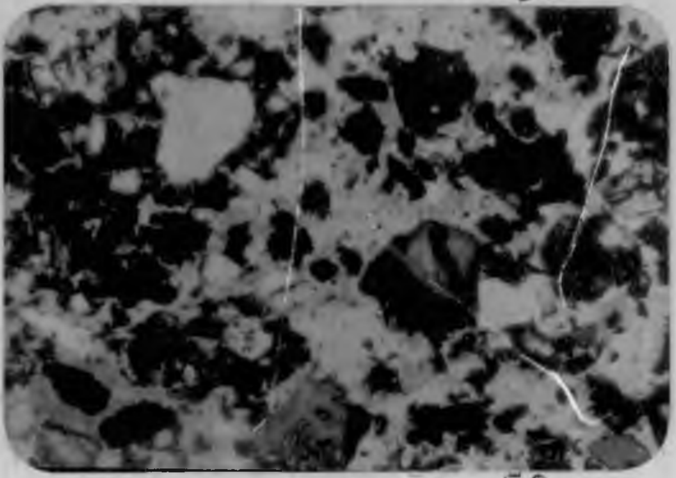

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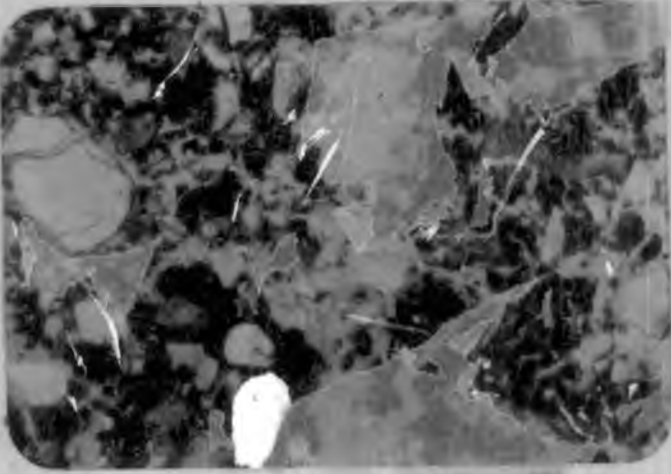

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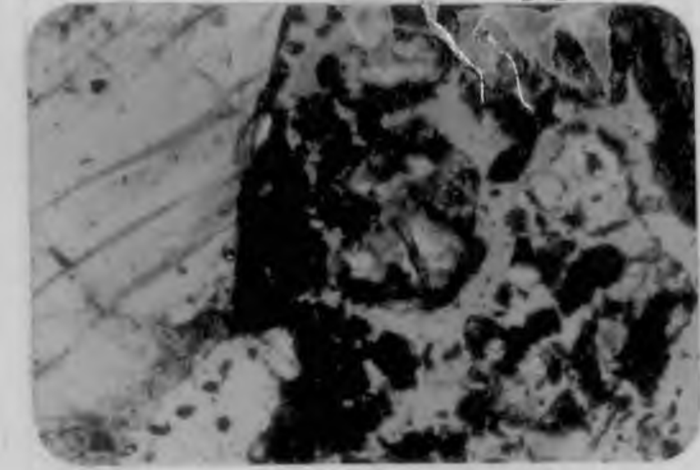

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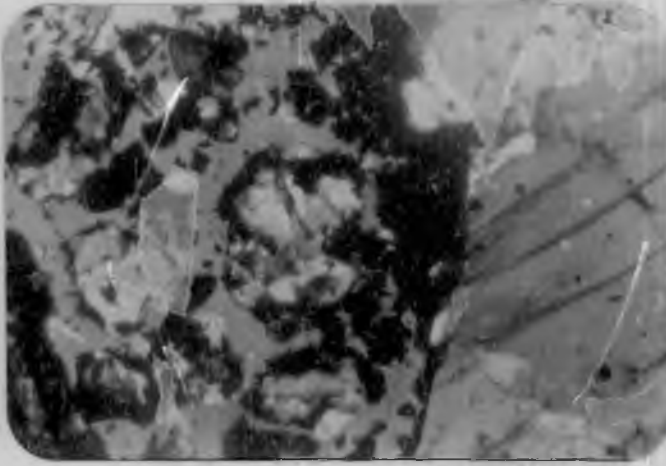

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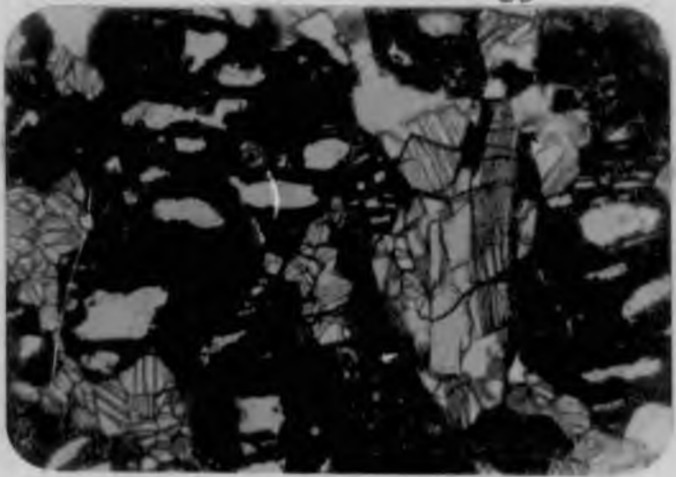

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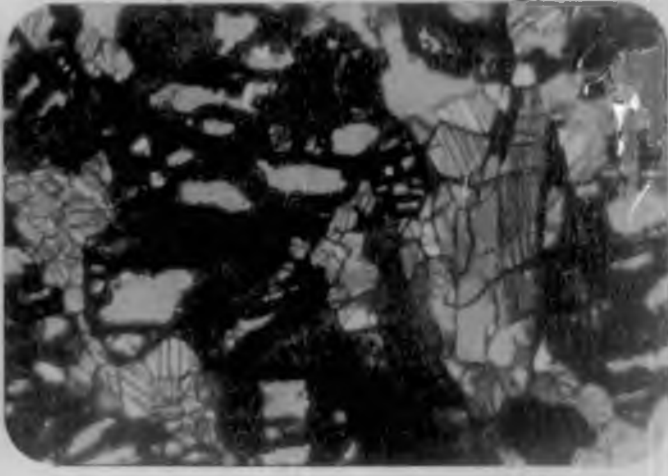

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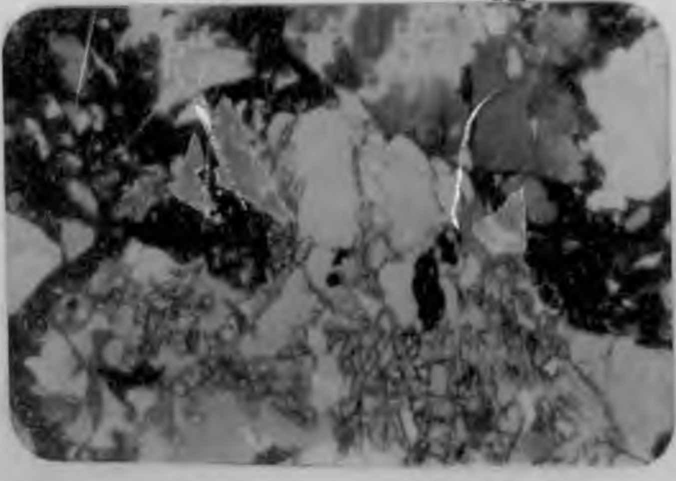

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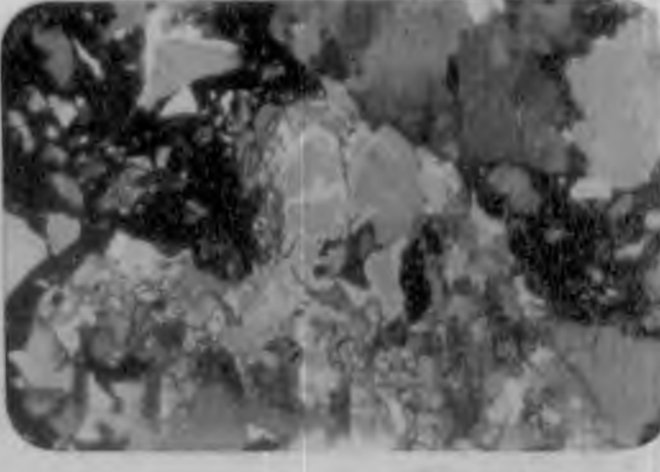

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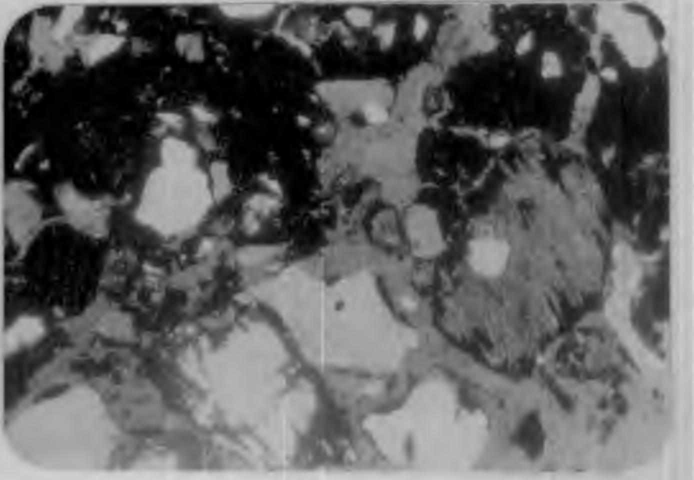

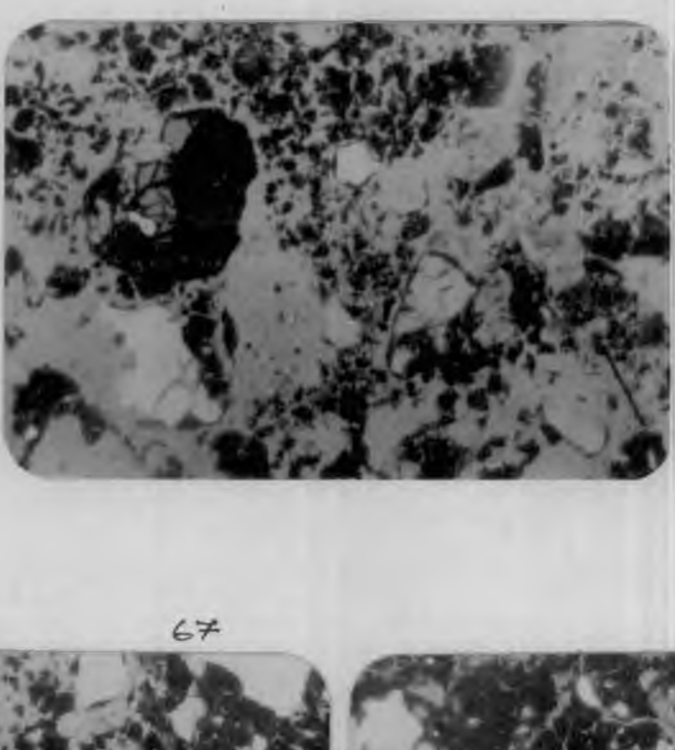

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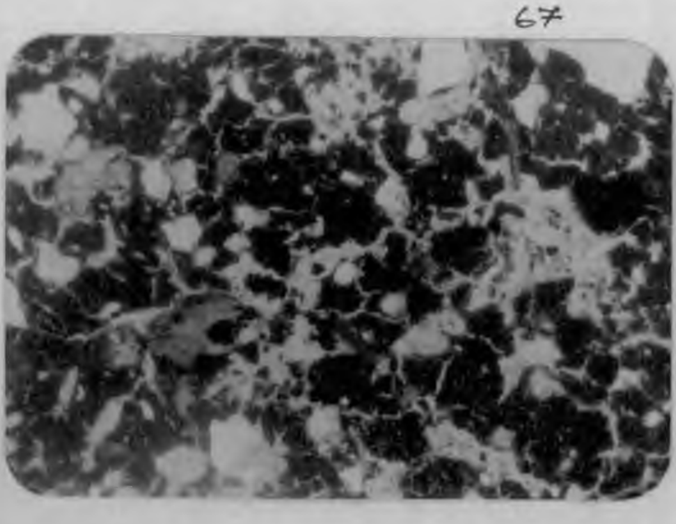

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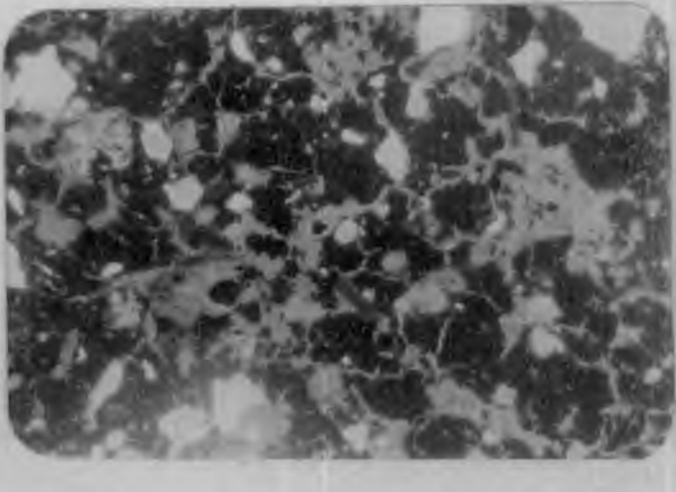

of the soil was granic to grani-plasmic except that under cashew where the NHDP was porphyric.

Coarser/finer

Irrespective of the profile, the surface soil was coarser and free and the lower layers were finer and compact. When compared these features under different vegetation, soil under evergreen forest exhibited a peculiar coarser feature throughout the profile (Plates No.41 to 48).

Voids

The surface soil was porous and the compaction progressively increases down the profile. In general surface soil was with planar and packing voids while massive compacted subsurface laterised layers were with channels, chambers and vughs. In shola forest, the soil towards the surface was compacted with channels and chambers. This feature was progressively expressed in eucalyptus and cashew plantations. The dominance of vugh and metavugh was a peculiar feature observed in soils under tea and semi-evergreen forest.

Humus

Humus was present intimately mixed with iron as macro aggregates of scattered entity. The macro aggregates were with reinforcement by less than silt sized subangular to subrounded quartz skeletons. A peculiar feature of this arrangement of macro and micro aggregates were evidonced by the characteristic dark brown, reddish brown and yellowish brown colour with sharp or faint dark margin.

Cutans

The dominant cutans observed were faint margined ferri-organan in the surface, sharp margined forran and ferriargillan in the subsurface layers. Organic matter was seen present as intimately mixed ferriorganan even in soils under pure plantation (Acacia). Cutans were present surrounding the skeletons and voids. Cutans and their macro aggregates and finer fraction together constituted the whole soil coatings surrounding the comparatively bigger voids. Complete bridging of skeletons with micro and macro organic matter aggregates of dark brown to dusk brown colour was predominant in the evergreen, semi-evergreen, shola, tea and even in acacia while this was not noticed in the other forests and plantation soils studied.

Lithorelic

All the profiles were gravelly throughout except in the case of shola, evergreen and cashew where the sub-surface soil was finer, massive and argillaceous. The soils under acacia and eucalyptus were finer to granular in the surface and without gravels almost throughout the profile.

The soil under acacia exhibited light grey colour to dark grey throughout the profile and they were firm dry almost throughout the profile.

DISCUSSION

Physiographic position of the profile location an
influence on soil development

The geomorphology of the eight profile loca
is presented in Table 1. The different profiles
located within the latitude of 8° 41' to 8° 46' a
logitude of 77°6' to 77°8' but at different eleva
ranging from 200 to 1030 m. The profiles represe
deciduous and semi-evergreen ecosystems are locat
lower altitudes of 200 to 230 m above MSL while t
evergreen and shola ecosystems are at higher alti
(650 to 1030 m). The profile locations at lower
higher altitudes enjoy different climate mainly d
the manifestation of the latitude. The mean maxi
minimum and annual temperature of the low land lo
are 32.6°C, 21.9°C and 27.3°C respectively while
the high land locations are 29.4°C, 19.3°C and 24
respectively (Table 3). The amount of precipitat
the high land locations is 4184.1 mm, whereas tha
the low land locations is only 2177.3 mm (Table 2
the profiles are located in rolling or undulating
graphy which provides good drainage, a pre-requsi

Geologically, all the soils studied are developed from the same parent material granite-gneiss of Archaean age. Since the soil under the natural forests are protected by the forest vegetation from the direct action of weathering forces such as solar radiation, precipitation and wind, they are not subject to severe movements and therefore retain the juvenile nature, whereas those from planted forests are found to be in a more senile state. The laterisation index of the low land locations is 32.1 while that of high land locations is 36.8 (Table 4). Inspite of the high rainfall, the low L value observed is due to the modifying effect of the mean minimum temperature.

Type of vegetation and its influence on the soils

Important species prevailing in different profile locations are described under the heading 'Distribution of vegetation' in 'Results'. They are also depicted in photo plates 2, 4, 6, 8,10, 12, 14 and 16.

The dominant tree species in deciduous forest shed their leaves regularly and remain leafless during a part of the year, especially in autumn. The shola and evergreen forests on the other hand consist entirely of evergreen species which do not shed their leaves as noticed in deciduous species and remain green always. In semi-evergreen forests, the dominant species include both deciduous and evergreen types. The planted vegetations studied here are cashew, eucalyptus, tea and acacia.

The nutrient uptake and that biocycled through dead roots and litterfall vary largely with the type and age of the vegetation. The annual litter production and its chemical and physical nature are also influenced by the type of vegetation. Premakumari (1987) has reported that among the planted forests and plantations the litter production is in the order of eucalyptus > teak > rubber.

The canopy structure of different forests and planted vegetations vary widely with the type and age of the vegetation. The canopy of the deciduous forest is not dense while those of evergreen and shola are dense, many storied and unbroken. The solar radiation reaching the ground is comparatively more in deciduous forest than in semi-evergreen, evergreen and shola. The difference in canopy structure and litter layer on the floor due to the different types of vegetation also influence the micro-climate, moisture status and erodability of the soils in varying degree, which in turn affect the decomposition of organic debris on the floor. The decomposition of organic matter is found to be more in soils under planted vegetation and deciduous forest than under evergreen and shola.

The root activity of different vegetation varies very much. The tea and acacia have sent their roots deep in to the subsurface soil compared to the other type of vegetation. The increased root activity exhibited by these two vegetations helps them to withdraw nutrients from the lower illuvial zones where elluvial mineral nutrients are accumulated. Moreover, the binding action of the deep roots has strengthened the structural stability and improved the single value constants such as low bulk density, higher porosity and water holding capacity of the subsurface soil under tea and acacia (Table 5.3, 5.4 and 7).

The present study also reveals that acacia enriches the nitrogen status of the soil at a faster rate by its ability to fix atmospheric nitrogen.

Macromorphology

Colour

The surface soils of plantation as well as forest are dark brown or dark grey in colour due to the different soil content of humified organic matter. These colours also indicate that the soils are mostly uneroded. The yellowish red or yellow colour of the subsurface soils of deciduous, cashew, eucalyptus, evergreen and shola locations may be due to the influence of iron oxides mostly in its hydrated form which is a characteristic of moist soils. The dark red or reddish brown colours of sub-surface soils at semi-evergreen, tea and acacia sites indicate that these soils are rich in iron or iron oxides. These colours are also characteristic of intense weathering and emphasize the well aerated conditions that prevail throughout the profiles at all the locations.

The colours of laterite horizons are reddish brown or red where a hard plinthite is present. The yellow shade in evergreen (lowest horizon) shows that the plinthite is soft.

Structure

The structure of the soil in different ecosystems is not seen markedly altered as the same pattern of structure is observed in the corresponding plantation profile as well with only minor variations in size and grade. The granular and crumb structure observed in the surface soils may be due to the presence of high organic matter, faunal activity and lesser sesquioxide content.

A close examination of different profiles reveals that due to deforestation, the structure of the surface soil has been damaged to a certain extent. But the subsequent influence of different plantations has improved the structure almost to the original level. The increased root activity observed in tea and acacia plantations has improved the structure of the subsurface soil more than that of the corresponding forests.

Consistency

The friable, non-sticky and non-plastic nature of the surface soil irrespective of the profile are due to the comparative low content of clay and higher content of organic matter while the sticky and plastic nature of the subsurface soil indicate the presence of more clay and lesser content or organic matter. In evergreen forest profile, the lowest horizon exhibits a non-sticky and non-plastic consistency which is due to a very low content of clay and organic matter and a corresponding higher proportion of coarse sand.

Boundary

The smooth boundaries mostly seen in the forest profile indicate that the processes of leaching and capillary migration are balanced whereas the wavy boundaries observed in eucalyptus and acacia profiles are due to the intensive leaching and lessivage. Since the canopy of the two plantations is neither dense nor completely closed, the high precipitation and its direct action on soil without much interception by the canopy might have facilitated more intensive leaching leading to the formation of a wavy boundary.

Root activity

Medium and fine roots are seen commonly in the bottom soils of tea plantation while a few medium and coarse roots are observed in the bottom soil of the acacia plantation. In all other sites medium and coarse roots are almost absent in the lowest horizon. The increased root activity generally noticed in the surface soil irrespective of the location and in the subsurface soil of tea and acacia can be related to the structural stability of the soils.

Permeability

Irrespective of the location, all soils studied are found well drained and no water stagnation is noticed within the profile depth due to its optimum porous nature. The lowest horizon of eucalyptus plantation is seen somewhat impermeable which may be possiblydue to the high content of clay and/or the massive structure of the pallid zone.

Mottling

The mottling is rarely observed in most of the profiles under investigation. The mottling is generally found more in the lower layers with irregular colourations, which may be characteristically caused by alternate periods of dry and moist conditions. The reddish yellow, brownish yellow, red and yellowish brown streaks and spots indicate the oxide forms of iron and manganese. The grey mottles observed in the subsurface soil of acacia profile might be due to the absence of sufficient oxygen in that region.

Laterite horizon

Laterite horizon is generally soft and friable in forest profiles. It is present at the lowest region. The low content of clay and a corresponding higher content of sand fraction in addition to the yellow colour in the C horizon of the evergreen forest show that the vegetative cover results in less intense chemical weathering and is thus only in the initial stages of laterisation. In all plantation profiles, except acacia, laterite is present at the lowest horizon. In eucalyptus and tea plantations it is slightly hard and friable while in cashew it is moderately soft and friable. All these laterite layers are red, reddish brown and yellowish red in colour, massive and consists of more ferruginous clay and sand.

Erosion

The extent of erosion is slightly severe in deciduous forests and acacia plantation where the canopy closure is not complete.

Physical properties: Granulometric composition

The granulometric composition and textural ratios of the different soils collected from various profiles are presented in Table 6.

Gravel

The proporties of gravel is significantly higher in all the profiles studied. Among the various components of the granulometric composition gravel is the most variable ranging from 17.46 to 52.75 per cent. In forest profile gravel content is found to be more in the sub-surface soil and its distribution shows a general pattern of increase with depth. Though a definite pattern of distribution is not noticed in plantation profile, gravel content is generally more in the surface soil except in cashew profile. The removal of forest cover and subsequent land preparation and cultural operation coupled with high rainfall might have facilitated downward translocation of the finer fraction. The consequent accumulation of gravel in the surface may be the prime cause for the comparatively higher content of gravels found in the surface soil of the plantation profile.

Coarse sand

The content of coarse sand fraction is significantly higher in forest profile than in the corresponding plantation profile in semi-evergreen and evergreen ecosystems whereas in deciduous ecosystem it is non-significant. In most of the forest profiles the sand content increases with depth while in plantation profiles it decreases with depth (Fig.1). This observation is in agreement with the findings of Thomas (1964). Gowaikar and Datta (1971)

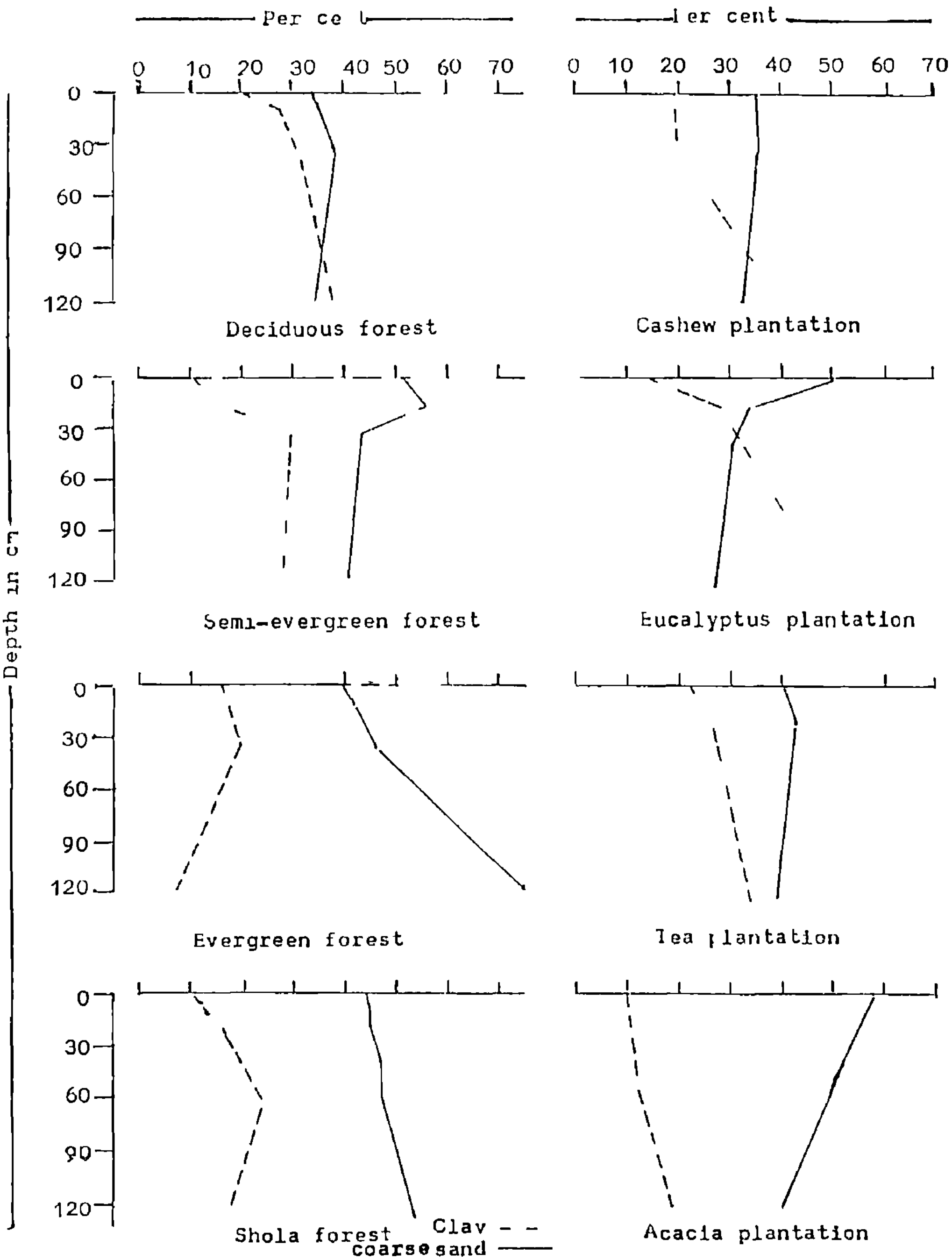

Fig 1 Variation in the contents of coarse sand and clay in different soil profiles

reported a decrease in the content of sand fraction with depth in most of the laterite soils. The decrease in sand content with depth noted in plantation profile might be an indication that laterisation is advanced as a result of deforestation.

Fine sand

The fine sand fraction increases with depth in shola ecosystem and decreases with depth in evergreen ecosystem while no definite pattern is observed in its distribution in deciduous and semi-evergreen ecosystems. No significant difference is noticed in the average content of fine sand between forest and plantation profiles within each ecosystem except in the case of deciduous where the average fine sand fraction is significantly higher in cashew soil (12.49 per cent) than in the deciduous forest soil (8.07 per cent)

Silt

In most of the profiles studied, the proportion of silt content is more in the surface soil than in the subsurface soil. The distribution of silt within the profile is found to be irregular.

Clay

The clay content in the forest soil varies from 11.80 to 36.19 per cent while in plantation soil it ranges from 10.79 to 43.59 per cent. In all the forest profiles except deciduous, the clay content increases with depth upto an intermediate horizon and then decreases whereas in plantation profiles it increases uniformly with depth. This observation is in confirmity with the findings of Thomas (1964) and Alexander et al (1981a).

The progressive decline in the content of sand fraction and a corresponding increase in the content of clay fraction with depth noticed in plantation profiles as compared to the forest profiles clearly indicate the fact that deforestation causes mechanical eluviation with a higher migration of clay colloids from surface downwards.

Among the forest profiles the highest content of average clay is observed in deciduous forest (28.85%) followed by semi-evergreen (21.32%), shola (19.43%) and evergreen (16.12%). Thomas (1964) has reported more clay in the soils of moist deciduous forest than in other types of forests. This indicates that soil weathering and clay formation is more advanced in deciduous forest followed by semi-evergreen, shola and evergreen. Because of the low temperature, high altitude and dense fully stocked canopy, weathering and clay formation proceed slowly in evergreen and shola forests as compared to deciduous and semi-evergreen forests. Among the plantation profiles a higher average content of clay is recorded in eucalyptus (30.83%) and tea (27.27%) than their corresponding forest profile viz. semi-evergreen (21.32%) and evergreen (16.12%) respectively. The average content of clay in cashew(23.43%)

and acacia (13.59%) soils is comparatively lower than their corresponding forest soils. This observation probably indicates that while the influence of tea and eucalyptus accelerates the process of weathering, influence of cashew and acacia delays the process compared to that of the corresponding forest vegetation. A high degree of weathering has been reported in the case of eucalyptus by Premakumari (1987) and in the case of tea by Elizabeth Chacko (1988).

Textural ratios

The fine sand to coarse sand ratio of forest soil varies from 0.16 to 0.34 while 0.12 to 0.41 in plantation soil. The mean values of the ratio for deciduous, semi-evergreen, evergreen and shola forests are 0.23, 0.20, 0.26 and 0.24 respectively while 0.35, 0.28, 0.30 and 0.25 for cashew, eucalyptus, tea and acacia plantations respectively. The silt to clay ratio of forest soil varies from 0.43 to 2.39 while 0.38 to 2.01 in plantation soil. The eucalyptus soil records the lowest value of 0.38 while the highest value of 2.39 in soil under shola. The silt to clay ratio is an index of weathering and as such the higher values of the ratio registered in all the diagnostic horizons of the investigated profiles indicate a low degree of ferrallitization of the soils. There is no significant difference in the mean silt/clay ratio between forest and plantation soils within each ecosystem. But based upon the ratio, the soils can be arranged in the order according to the degree of weathering: eucalyptus > tea > deciduous > semi-evergreen > cashew > shola > evergreen > acacia.

The mean sand + silt to clay ratio of semi-evergreen forest (4.27) and evergreen forest (5.34) is higher than that of corresponding plantation soil viz. ecualyptus (2.34) and tea (2.61) respectively indicating that predominance of non-clay fraction contributes to the texture of the forest soil under semi-evergreen and evergreen forests. In all the forest soils except evergreen, the soil texture ranges from sandy loam in the surface to gravelly sandy clayloam in the subsurface. In evergreen forest the subsurface soil contains more sand and hence the texture is loamy sand. In the case of plantation soil, the texture ranges from loam (surface) to gravelly clay loam (subsurface) in cashew, gravelly sandyloam to gravelly clay in eucalyptus, gravelly sandy clay loam to clay loam in tea and gravelly sandy loam to sandy loam in acacia. The observation relating to eucalyptus and tea soils is in agreement with the findings of Rajamannar et al (1979) and Elizabeth Chacko (1988).

Single value constants

The data relating to the single value constants are presented in Table 7. Analysis of the data reveals that the effect of deforestation and subsequent influence of different plantations are reflected on the physical condition of the soil.

Bulk density

The bulk density for the surface soil is found lower at forest sites than for the corresponding plantation sites. The low bulk density of the surface soil of the forest profile is related to the high organic matter content and its very stable structure. The higher bulk density in the lower horizons of forest profile may be due to the filling up of pores by eluvial material. In plantation profile, the bulk density shows a higher value in the upper horizons as a result of the loss of stable structure due to the eluviation of materials and low organic matter content. Because of this the surface soil at plantation site is more sandy in texture. The low organic matter content and the sandy texture together with the loss stable structure of the soil tend the particles to be packed more closely together which might have been the cause for the higher bulk density exhibited by the surface soil at plantation site. Moreover, the clear cutting, removal of logs and subsequent land preparation and usual tillage operations for raising the plantation might have contributed to a certain extent compaction of the surface soil at plantation site resulting in higher bulk density.

Particle density

The particle density is slightly higher for the surface soil of plantation profiles compared to the forest profiles within the semi-evergreen, evergreen and shola ecosystems while it is almost same for profiles within the deciduous ecosystem.

Porosity, water holding capacity and volume expansion

The porosity and maximum water holding capacity of the soil samples range from 34.80 to 46.24 per cent and 26.40 to 42.49 per cent respectively. In all the profiles except evergreen and acacia, the porosity and the maximum water holding capacity are relatively higher in the surface soil than in the subsurface soil. Though the average values for porosity and maximum water holding capacity show no significant difference between forest and plantation profiles within each ecosystem, it records a lower value for cashew and eucalyptus plantations and a higher value for tea and acacia plantation compared to the corresponding forest profiles. Pathak et al (1964), Pritchett (1979), Gent et al (1983) and Premakumari (1987) have reported that deforestation and continuous cropping result in an increase in bulk density and particle density and a reduction in porespace and water holding capacity. In the present study also a similar variation is observed in soils under cashew and eucalyptus plantations in deciduous and semi-evergreen ecosystem respectively. The above single value constants of tea and acacia on the other hand exhibit a reverse trend wherein lower average values are recorded for the bulk density and higher values for the porosity and maximum water holding capacity. The unusual trend as noticed in tea and acacia plantations might be largely due to the increased root activity of the tea and acacia preferably in the sub-surface soil.

The volume expansion of the soil samoles of different profiles ranged from 3.83 to 10.29 per cent. Among the profiles, deciduous forest registers the highest average value of 7.89 per cent. The observed difference within and between the profiles can be related to their clay content. A strong positively significant correlation (+0.4996)** found to exist between these two characters of the soil highlights the influence of clay on volume expansion of the soil. The comparatively low volume expansion of the soil attributes the presence of non-expanding type of colloidal material - a qunique characteristic or laterite soils. No significant difference is noticed between forest and plantation profiles within each ecosystem indicating that the effect of plantation on volume expansion is less pronounced.

Aggregate stability and mean weight diameter

The percentage aggregate stability of soil samples varies from 21.26 to 96.62 in forest soil while 31.58 to 87.27 in plantation soil. The percentage aggregates are generally higher in forest soil than the corresponding plantation soil in all ecosystems except in shola where it is significantly higher in acacia plantation (81.15) than the corresponding shola forest (51.91). The mean weight diameters (MWD) in forest soil are within the range of 2.05 to 4.49 mm and in the plantation soil from 2.31 to 3.54 mm. The greatest differerce in MWD is found between profiles within the semi-evergreen ecosystem though the difference is marginal. In general, the average MWDs of forest profile are comparatively higher than the plantation profile in all ecosystems except shola. The water stable aggregates are higher in surface than in the subsurface soil in all the forest profiles whereas in plantation profiles it is relatively higher in the subsurface soil. This observation is in agreement with the findings of Hulton, B.wood (1976) and Wilfred Godwin (1986). A significant positive correlation ($+0.3663^{*}$) is observed between percentage soil aggregates and organic matter and between percentage aggregates and DTPA extractable iron ($+ 0.4380^{*}$) . The difference in aggregate stability observed among the soils is largely related to the difference in the contents of organic matter, DTPA extractable iron and the binding action of roots.

Chemical properties

Soil reaction

Table 8 presents the soil reaction of various horizons of different profiles. The pH value in distilled water(pH w) shows that the soils are acidic in reaction. In forest soil it varies from 4.2 (deciduous and shola) to 4.9 (deciduous) while 4.2 (cashew and eucalyptus) to 6.4 (tea) in plantation soil. Among the forest profiles the mean value of pH w recorded a minimum of 4.28 in shola and a maximum of 4.57 in evergreen. The mean value of pH w in plantation profiles registered a minimum of 4.6 in acacia and a maximum of 5.6 in tea. The data indicate that the soils of natural forests are slightly more acidic than their corresponding plantation soils except in semi-evergreen ecosystem where the eucalyptus plantation shows a relatively lower pH than the corresponding forest soil. Between forest and plantation profiles, no marked difference is noticed within the deciduous, semi-evergreen and shola ecosystems while in evergreen ecosystem the pH of tea plantation is significantly higher than the corresponding evergreen forest. The increase in pHw observed in plantation soil may be due to the incorporation of ash in the soil during burning operation connected with the deforestation

(Thomas, 1964) or by checking the subsequent accumulation of organic matter (Riquier, 1953) or due to the removal of soluble salts by leaching or by any combinations of the above (Fuller, 1955). The higher accumulation of organic matter on the forest floor and its decomposition releases organic acids which are responsible for the higher acidity of the forest soil.

The pHw value recorded in the deciduous forest is the lowest among the forest soils. This observation is inconfirmity with the findings of Thomas (1964). According to him the soils of most deciduous forest have a higher degree of acidity.

A lowering of pH observed in eucalyptus plantation than the corresponding semi-evergreen forest is in agreement with the findings of Tofey et al (1986). The eucalyptus leaves and litter have a low ash content (Premakumari,1987) or the uptake of more cations from the soil by the plantation might be the probable reason for the lower pH of the soil under eucalyptus.

The low acidity (higher pHw) of tea soil can be attributed to the presence of a higher content of bases such as calcium (1070 $\mu g\ g^{-1}$) and magnesium (4467 $\mu g\ g^{-1}$) of the soil. The regular use of fertilizers such as rock phosphate containing the bases and the relatively low uptake of the bases from the soil by tea might have led to the build up of these basic elements in the tea soil. A similar observation has been reported by Mann and Gokhale (1960) that most tea soils of south India show a pH value between 4.5 and 6.0, the figure is higher in some cases.

Irrespective of the profile, the surface soil is generally less acidic than the subsurface soil. This observation is in line with the findings of Doyne (1935). According to him such a condition tends to prevail in soils that support the type of vegetation whose foliage contain a high content of bases.

The pH in I N sodium fluoride (pHs) registers a higher value for all the soils than the pH obtained in distilled water. The rise in the pHs is due to the displacement of OH by the fluoride ions indicating that the soils have net positive charges due to the dominance of the exchangeable complex by hydrous iron oxides. The pHs is increased by 2.7 to 6.4 units in forest soil while 1.6 to 6.6 units in plantation soil. Cashew soil shows the maximum increase of 6.6 units while the minimum increase of 1.6 is observed in tea soil. No significant difference is observed between forest and plantation profiles within each ecosystem.

The pH in I N potassium chloride solution (pHk) of all the soil samples is found lower than that in water, the lowering being in the range of 0.1 (cashew and tea) to 0.7 (evergreen) units. A significantly higher pH is observed in tea soil than the corresponding forest soil. When the soil is treated with the neutral KCl solution the hydrogen ion gradient across the double layer around the clay colloidal system gets compacted liberating H^+ in to the soil solution and the consequent reduction in pH gives an indication of the exchangeable acidity. The minimum lowering of the pHk compared to the pHw in cashew and tea soil may be due to the low exchangeable acidity of the soil while the maximum lowering of the pHk noticed in the evergreen forest soil indicates that the soil has a high exchangeable acidity compared to other soils.

The pH value of the soils in 0.01 M calcium chloride solution (pHc) shows a reduction of 0.2 (cashew) to 0.7 (semi-evergreen forest) unit than that in distilled water. A significantly higher pH c value is observed for tea soil as in the case of pHk.

The present investigation reveals that the tea soil is weakly acidic, soils under semi-evergreen, evergreen, cashew and acacia are medium acidic while deciduous, eucalyptus and shola soils are strongly acidic.

Conductivity

Table 8 presents the data pertaining to the electrical conductivity of various soil samples in different profiles.

The electrical conductivity for tea soil is significantly higher than the corresponding forest (evergreen) soil indicating that the soil is abundant in soluble salts. Irrespective of the profile, the electrical conductivity is found to be decreasing with depth. This observation shows that water soluble salts are predominant in the surface soil than in the subsurface soil in all the profiles under investigation. No significant difference is observed in the mean value of electrical condcutivity among the profiles except tea.

Cation exchange capacity

Being an integrative property of the soil, cation exchange capacity (CEC) is a measure of soil fertility. From the data presented in Table 8 it can be seen that in most of the profiles CEC decreases with depth. Inspite of the low clay content, the higher CEC observed for the surface soil reveals that the CEC is mostly contributed by the organic matter. In deciduous and eucalyptus profiles an increase in CEC is noted at the lowest horizon, which may be due to the presence of a comparatively higher content of clay in that horizon. Though a higher content of clay is present in the diagnostic horizons, the low CEC (4.2 to 11.3 Cmol (p^{+}) kg^{-1}) observed in these horizons indicates that clay is of non-expanding Kaolinitic type. The low CEC exhibited due to the predominance of clay is a characteristic feature of laterite soils as evidencedby Satyanarayana and

Thomas (1962), Gopalaswamy and Nair (1972) and Thomas (1981). Though no significant difference is noticed between the forest and plantation profiles within each ecosystem a higher mean value is observed for cashew profile (12.67 Cmols $(p^+)kg^{-1}$) than for other profiles. CEC is found positively and significantly correlated to organic matter $(+0.3794^*)$ and DTPA extractable iron $(+ 0.4540^*)$. A strong positively significant correlation is also observed between CEC and DTPA extractable aluminium $(+ 0.5590^{**})$

Organic carbon and organic matter

The data presented in Table 9 suggest that irrespective of the profile, the surface soils generally have a higher content of organic matter which decreases steadily with depth. The organic carbon content is higher in the surface soil of forest compared to the corresponding plantation soil. The distribution of organic carbon with depth in different soil profiles is illustrated in Fig.2. The highest value of 3.05 per cent is recorded in deciduous forest. The higher content of organic carbon in the surface soil of forest can be attributed to a comparatively slow rate of decomposition of organic matter as a result of canopy closure or to a higher rate of accumulation oforganic matter by way of profuse litter fall which is more pronounced in deciduous forest during winter season or both.

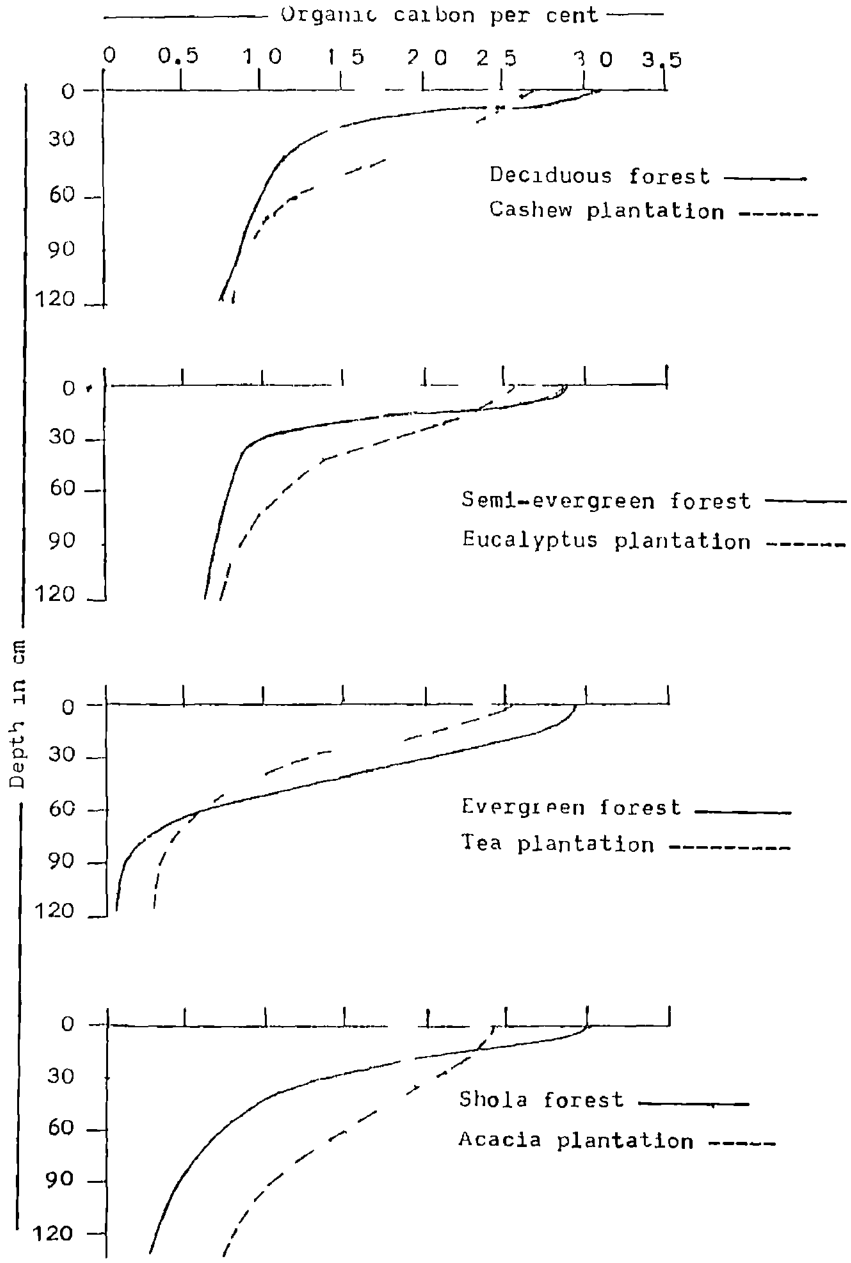

Fig.2 Variation in the content of organic carbon in different soil profiles

The average content of organic carbon shows a higher value for eucalyptus and acacia profiles while a lower value for cashew and tea profiles compared to the corresponding forest profiles. Balagopal and Alexander (1983) reported that higher levels of organic carbon occurred in teak, eucalyptus and albizzia plantations compared to the natural forests. The plantation profiles in general show a comparatively lower value for the surface soil and a higher value for the subsurface soil with respect to that for the corresponding forest soil. This observation in fact indicates that organic carbon has been partly leached off and eroded off and partly burnt faster due to denudation. Thomas (1964) working with the forest soils of Kerala has reported a similar observation. According to Chaly (1965) the organic matter content is considerably reduced after denudation and there is a tendency for the level of carbon in the lower layers to increase with increased period of denudation.

The influence of organic matter on the extent of laterisation has been subjected to the study of many soil scientists. Schwertmann (1966) and Walker et al (1969) have observed a negative relationship between organic matter content and induration. They have also observed that increase of organic matter content inhibits ferrallitization in a conducive laterite environment.

According to Thomas Varghese (1981) an organic matter level less than 5 per cent in the surface soil leads to ferrallitization in a conducive laterite environment. However, the present study indicates that ferrallitization advances more in the shola forest even if the level of organic matter in the surface soil is 5.19 per cent and at the same time significant ferrallitization has not been observed in acacia soil having 4.07 per cent organic matter in the surface soil under the same ecosystem. The intricacies of the role played by different types of vegetation in the manifestation of laterisation are yet to be explored and the extent of laterisation thus cannot be discussed merely on the basis of the level of organic matter in the soil.

Nitrogen (total and available) and C/N ratio

The data presented in the table 9 indicate that there is no significant difference among the profiles in the case of total nitrogen, available nitrogen and C/N ratio. Irrespective of the profile, the total nitrogen decreases with depth. Based on the content of average total nitrogen, the forest profiles can be arranged in the decreasing order of: deciduous, evergreen, semi-evergreen and shola. The average content of total nitrogen is relatively higher in plantation soil than in the forest soil within deciduous, semi-evergreen and shola ecosystems, the difference being greatest between acacia and shola (0.053%) in the shola ecosystem. The present study reveals that acacia enriches the nitrogen reserves of the soil at a faster rate by its ability to fix nitrogen, much of which is returned to the soil. Adoms and Attiwill (1985) have estimated the rate of nitrogen fixation by Acacia spp. as 12-32 kg ha^{-1} year $^{-1}$ which confirms the role of acacia as a fast growing pioneer species important in maintaining the nitrogen pool of its ecosystem.

Though acacia and cashew profiles register the highest value in the content of average total nitrogen (0.183%), the content of average available nitrogen recorded in these profiles (73 and 78.33 µg g^{-1}of soil respectively) is the least compared to other profiles. At the same time, the shola forest which has recorded the lowest content of average total nitrogen (0.13%) contains, the highest amount of average available nitrogen(95.8 µg g^{-1}). The comparatively higher amounts of available nitrogen observed in eucalyptus and tea soils than the corresponding forest soils reveal that nitrogen mineralisation is at a faster rate in these soils. In plantation profile the subsurface soil is characterised by the presence of relatively higher values of total and available nitrogen than the corresponding forest profile indicating that the decomposition and mineralisation of organic matter and leaching to a lower depth have been taken place at an increased rate in plantation sites immediately after clear felling. The total nitrogen shows a strong significantly positive correlation with organic carbon (+0.9684)**, silt/clay ratio (+0.6403)**, electrical conductivity (+0.6112)** and pore space (+0.5216)**. A significant positive correlation is also observed between total nitrogen and pH in water (+0.4118)* and between total nitrogen and CEC(+0.3695)*.

The C|N ratio varies from 13.2 to 2.4 in forest soil while 10.9 to 6.5 in plantation soil. The higher level of C|N ratio in the surface soil of forest profile compared to that of the corresponding plantation profile indicates the accumulation of relatively higher amount of undecomposed organic matter in the forest floor while the process of decomposition is quite rapid in plantation site.

Total and available phosphorus

The total and available phosphorus status of different soils are presented in Table 9. The total content of phosphorus in forest soil ranged from 0.031 to 0.171 per cent while 0.039 to 0.213 per cent in plantation soil. Among the forest profiles, shola recorded the highest value of average total phosphorus (0.0962%) followed by semi-evergreen (0.0701%), evergreen (0.0627%) and deciduous (0.0603%). A slight increase in the content of average total phosphorus is noticed in plantation profile compared to the corresponding forest profile irrespective of the ecosystem. This observation is in line with the findings of Thomas (1964). According to Adams and Boyle (1980) such an increase in phosphorus content after deforestation might be through the mineralisation of organic matter. Phosphorus is generally seen accumulated in the middle horizons in forest profile, whereas in plantation profile its distribution shows no definite pattern. The higher content of clay present in the middle horizons of the forest profile might have retained more phosphorus in this region.

The available phosphorus status of the soils studied is poor and varies from trace to 17.1 $\mu g\ g^{-1}$ of soil. A similar observation has been reported for laterite soils by Subramonia Iyer (1979). Irrespective of the profile, its distribution down the profile is random. Among the forest profiles, evergreen registered the highest value of average available phosphorus (5.13 $\mu g\ g^{-1}$ of soil) followed by deciduous semi-evergreen and shola. The content of average available phosphorus is found to be higher in tea and eucalyptus soils compared to the corresponding forest soil. This observation can be attributed to the higher pH and availability of calcium as evidenced in tea soil or due to the higher activity of micro organisms which increases the rate and amount of organic matter decomposition. The available phosphorus is significantly and positively correlated with soil pH($+0.8488^{**}$), water soluble iron ($+0.5425^{**}$), exchangeable zinc($+0.6137^{**}$), calcium (+0.8387**), water soluble aluminium (+0.4540*) and magnesium (+ 0.4231*) which show the intimate relation of available phosphorus with these soil parameters.

Total and available potassium

The total and available contents of potassium are showed in Table 9. In forest profile potassium is concentrated in the soils of upper horizons. In soils of younger plantations such as acacia (3 year old) and eucalyptus (4 year old) it is accumulated more in the lower layers. A similar result has been reported by Jose (1968) in 1 year old teak plantation. The higher accumulation of potassium in the lower layers of younger plantation might be as a result of increased leaching following deforestation. In older plantations (cashew and tea) as well as in natural forest potassium is rapidly and efficiently phytocycled and in effect a very little potassium is appeared to be leached downwards. Among tho forest soils, semi-evergreen shows the highest value of average total potassium (0.308%) followed by shola (0.236%), deciduous (0.204%) and evergreen (0.174%). This gradient in the content of potassium among the forest soils can be related to the potassium bearing minerals such as mica, feldspar etc. present in these soils. Though no significant difference is observed in the average content of total and available potassium between forest and plantation profiles within each ecosystem its contents are slightly highor in cashew and acacia soils, whereas slightly lower in eucalyptus and tea soils than the corresponding forest soils. The distribution of available potassium is found to be similar to that observed in the case of total potassium. The available potassium content of the soil is significantly and positively correlated to silt/clay ratio (+0.4556)*, sand + silt/clay ratio (+0.3996)*, and pH in water (+ 0.4486)*. It is strongly significant and positively correlated to organic carbon (+ 0.5046)** and electrical conductivity (+ 0.5707)* while total potassium is strongly and positively correlated to the pH in NaF (0.5317)**.

Calcium and magnesium

The calcium and magnesium status of various soils are presented in Table 9. Among the forest profiles,calcium concentration is found highest in semi-evergreen forest (283 $\mu g\ g^{-1}$) while the lowest concentration is in evergreen forest (27 $\mu g\ g^{-1}$). The average content of calcium is relatively lower in all plantation soils except in the case of tea, compared to the corresponding forest soil: Jose (1968) observed that during the prolonged process of thinning and clear felling of forests, the bases liberated from the decomposition of organic matter got quickly and perferentially leached down the profile. Koyamu and Nambiar (1978) observed that calcium content of soil is lowered by 4.3 to 65.2 per cent as a result of cultivation.

Silk worth and Grigal (1982) have reported that calcium losses as a result of deforestation is not compensated by inputs. In the present study a significant increase in the content of calcium is observed in tea soil(635.67 $\mu g\ g^{-1}$) than the corresponding evergreen forest soil (60 $\mu g\ g^{-1}$). The higher build up of calcium in tea soil can be attributed to the regular application of fertilizers containing this element.

The loss of calcium beyond the soil profile favours ferrallitization provided other conditions are conducive for the process. The extent of laterisation can be related to the low content of calcium of these soils.

In the case of magnesium the highest concentration of 2156 $\mu g\ g^{-1}$ noticed in shola forest while the lowest concentration of 112 $\mu g\ g^{-1}$ in evergreen forest. The average content of magnesium shows a significant increase in acacia (3279.67 $\mu g\ g^{-1}$) and in tea (2871.67 $\mu g\ g^{-1}$) and a non-significant increase in cashew (922.67 $\mu g\ g^{-1}$) soil than the corresponding forest soils namely shola (1568.20 $\mu g\ g^{-1}$) evergreen (822 $\mu g\ g^{-1}$) and deciduous (736.75 $\mu g\ g^{-1}$) respectively. Mineralisation of abundant organic matter and release of magnesium coupled with lesser utilization by the plantation crops are considered to be the cause for the increase in the concentration of the element. At the same time, a lower content of magnesium in eucalyptus soil than the corresponding forest (semi-evergreen) soil and an increasing trend in its concentration down the profile give evidence of preferential leaching of the element following deforestation. The highest concentration of magnesium in tea soil may be due to the application of fertilizer containing this element.

In most profiles calcium and magnesium are found accumulated in the upper horizons than in the lower horizons. Samra et al (1983) have reported that deep rooted vegetation phytocycled about 4 times or more calcium and magnesium enriching the A horizon with more of calcium and magnesium as compared to B and C horizons.

Fertility status

Forest soils are inherently fertile though it varies with forests in different ecosystems. The average CEC varies from 5.95 to 10.71 Cmol (p^+) kg^{-1} in forest soils in the order of evergreen $<$ shola $<$ semi-evergreen $<$ deciduous. The fertility status of deciduous forest soil is superior in the content of organic matter and nitrogen while medium in the content of potassium and calcium and comparatively poor in phosphorus and magnesium when compared to other forest soils. The semi-evergreen forest soil is superior in the content of calcium while medium in the status of organic matter, nitrogen, phosphorus, potassium and magnesium. The fertility status of evergreen forest soil is medium in organic matter, nitrogen and phosphorus while poor in bases such as potassium, calcium and magnesium. The status of shola forest soil is superior in the content of phosphorus and magnesium while medium in the case of potassium and calcium and poor in organic matter and nitrogen compared to other forest soils. Yadav (1968) reported that soils under different forest vegetation differed considerably in their physico-chemical characteristics.

There are different opinions about the effect of deforestation on soil fertility. Muller (1887), Mc Donald (1955) came to the conclusion that clear felling had no harmful effect while Riquier (1953) and Evans(1976) stated that clear felling and raising pure crops are detrimental because of the resultant hazards such as soil erosion, depletion of nutrients etc. that may alter the neutral equilibrium of the soil. While reviewing the effects of deforestation Wiedemann (1934) has pointed out that the effect of clear felling of forests cannot be generalised for all situations. In some cases an unfavourable effect, in others a favourable influence is obtained as a result of deforestation.

The present investigation reveals that deforestation and subsequent raising of plantation have marginally affected the fertility status of the soil and it varies depending upon the influence of the type of plantation. The CEC of the soils has been increased in deciduous and evergreen ecosystems due to the influences of cashew and tea respectively while it is found lowered in semi-evergreen and shola ecosystems where eucalyptus and acacia are planted respectively. Status of nitrogen, phosphorus, potassium and magnesium has been increased while organic matter and calcium contents are decreased in deciduous ecosystem due to the influence of cashew. As a result of the influence of eucalyptus, organic matter and phosphorus status has been marginally increased while nitrogen, potassium, calcium and magnesium status decreased in the semi-evergreen ecosystem. In evergreen ecosystem the status of phosphorus, calcium and magnesium has been increased while that of organic matter and potassium has decreased due to the influence of tea. The nitrogen status of the evergreen ecosystem has been found little affected by tea. While enhancing the status of organic matter, nitrogen, potassium and magnesium, acacia lowers the status of phosphorus and calcium in the shola ecosystem.

Iron and aluminium

Forms and distribution of iron and aluminium in different profiles are given in Table 11. All the soils studied here are dominated by iron and aluminium. The distribution of iron and aluminium shows an increasing trend with depth in most profiles. The lower content of iron and aluminium in the surface soil compared to subsurface soil in most profiles might be due to intense weathering and distribution of the primary minerals and subsequent leaching of the products including iron and aluminium which is an expression of the juvenile nature of the soil. The percentage of total iron in forest soil varies from 0.636 (evergreen) to 2.485 (shola) while 2.267 (cashew) to 4.772 (acacia) in plantation soil. The content of aluminium ranges from 4.853 per cent (evergreen) to 14.213 per cent (shola) in forest soils and 7.497 per cent (cashew) to 14.082 per cent (eucalyptus) in plantation soils. In general, the plantation profile contains relatively higher amount of average total iron and aluminium than the corresponding forest profile. Based on the total iron content, the profiles can be arranged in the decreasing order of acacia, eucalyptus, shola, cashew, tea, deciduous, semi-evergreen and evergreen. A higher proportion of aluminium noticed in all the profiles with respect to iron place the soils under the category of ferrallitic soils.

The total iron is significantly and positively correlated to pH in NaF (+0.4498*) and negatively correlated to available potassium (-0.4082*). The total aluminium is highly significant and positively correlated to clay(+0.5528**). The correlation and distribution of aluminium indicate that aluminium released during the course of weathering might have passed into the clay minerals.

The water soluble iron varies from trace to 14 $\mu g\ g^{-1}$ in forest soil while in plantation soil it ranges from trace to 50 $\mu g\ g^{-1}$. Irrespective of the profile, the maximum content of this form tends to concentrate in the upper and middle horizons leaving only traces in the lowest horizon. The water soluble iron is significantly and positively correlated to pH in water (+ 0.7207*), total calcium (+ 0.6353*) and magnesium (+ 0.5407**). A significantly higher content of average water soluble iron observed in the tea soil (21.3 $\mu g\ g^{-1}$) might be due to the intimate relation of this form of iron with the above parameters.

The ammonium acetate extractable iron (exchangeable iron) varies from 28 to 154 $\mu g\ g^{-1}$ of forest soil, whereas from 24 to 192 $\mu g\ g^{-1}$ in plantation soil. The DTPA extractable iron content at the same time ranges from 3 to 439 $\mu g\ g^{-1}$ and from trace to 456 $\mu g\ g^{-1}$ in forest and plantation soils respectively. In all the profiles studied, the distribution of these forms of iron shows a steady decrease with depth. The average contents of these forms of iron are relatively more in plantation profile though no significant difference is noticed between forest and plantation profiles within each ecosystem. The DTPA extractable iron is significantly and positively correlated to silt/clay ratio (+ 0.7152**), aggregate stability (+ 0.4380*), CEC (+ 0.4540*) and organic matter (+ 0.6800**) and negatively correlated to clay(-0.4382*).

The water soluble aluminium constitutes 2 (deciduous) to 185 $\mu g\ g^{-1}$ (tea) of the soil while ammonium acetate extractable aluminium ranges from 43 (tea) to 304 $\mu g\ g^{-1}$ (eucalyptus) and DTPA extractable Al from 2 (tea) to 566 $\mu g\ g^{-1}$ of soil (deciduous). The water soluble and DTPA extractable aluminium are observed to be higher in the upper horizons than in the lower horizons while no definite pattern is evident in the distribution of exchangeable aluminium. The water soluble aluminium is positively and significantly correlated to pH in water (+ 0.5333**), available phosphorus (+ 0.4540) and organic matter (+ 0.4903**). The DTPA extractable aluminium is significantly and positively correlated to silt/clay ratio (+ 0.5018**), aggregate stability (+0.3914**), CEC (+0.5590**) and organic matter (+ 0.5361**).

The dithionite extractable iron ($Fe_{(d)}$) varies from 5480 (evergreen) to 25440 $\mu g\ g^{-1}$ (shola) in forest soil while 11480 (cashew) to 31160 $\mu g\ g^{-1}$ (acacia) in plantation soil. Among the forest profiles, the highest average value of dithionite iron is observed in shola followed by deciduous, semi-evergreen and evergreen. The average value of dithionite extractable iron is found to be higher in all plantation profiles than the corresponding forest profiles and the increase in the content is significant in acacia and eucalyptus soils compared to the corresponding forest soils. Irrespective of the profile, the content of $Fe_{(d)}$ increases with depth. A close examination of the data reveals that in all these soils iron is mostly in its crystallised form. The colour of the soil can be related to the degree of crystallization and its mobility with in the profile. The $Fe_{(d)}$ is significantly and positively correlated to clay (+ 0.4607*) and negatively to organic matter (-0.4697*) which confirm the fact that the iron moves along with clay colloidal fractions down the profile.

The orxalate extractable iron ($Fe_{(o)}$) represents the amorphous form of iron which ranged from 190 to 5640 $\mu g\ g^{-1}$ in forest soil and 1080 to 10470 $\mu g\ g^{-1}$ in plantation soil. Based on the average $Fe_{(o)}$ content the forest soils can be arranged in the order: shola > deciduous > semi-evergreen > evergreen. Higher values are observed in plantation profile than the corresponding forest profile. Though a definite pattern of distribution is not evident, the values of $Fe_{(o)}$ in most of the profiles are generally greater in the middle horizons. The $Fe_{(o)}$ is present relatively in smaller quantities when compared to the $Fe_{(d)}$ which reveals that in well drained soils iron remains mostly in crystalline form. The $Fe_{(o)}$ is significantly and positively correlated to the organic matter (+0.5681**) and negatively and non-significantly to clay. This observation shows the intimate relation of this form of iron with organic matter. The strength of the soil has a positive relation with the $Fe_{(d)}$ and a negative relation with the proportion of $Fe_{(o)}$ (Shadfan et al. 1985).

Active iron ratio

The values of active iron ratio are within the range of 0.05 to 0.38. The higher value in surface soil is recorded in shola and evergreen (0.38) followed by semi-evergreen (0.30), deciduous (0.28), cashew (0.27), acacia (0.22), tea (0.21) and eucalyptus (0.15). The higher values observed in the surface soils of forest profiles compared to that of the plantation profiles explains the relative enrichment of amorphous oxides of iron than the crystalline form and thereby the relative juvenile nature of the forest soil. The active iron ratio steadily decreases with depth in all the profiles except acacia where a reverse trend is observed (Fig.3). The ratio is correlated significantly and positively to silt/clay ratio (+ 0.6163**) and organic matter (+0.5681**) but significantly and negatively to clay (-0.6486**). These relationships clearly show the inhibitory effect of organic matter in the crystallization of iron oxides. Schwertmann (1966) has demonstrated the inhibitory effect of organic compounds in the crystallization of iron oxides. A similar observation has also been reported in high land forest soils by Thomas Varghese (1981).

On critical examination of the average value of the active iron ratio it is found that the ratio is higher in forest soil than in plantation soil within semi-evergreen and evergreen ecosystems while a reverse trend is noticed

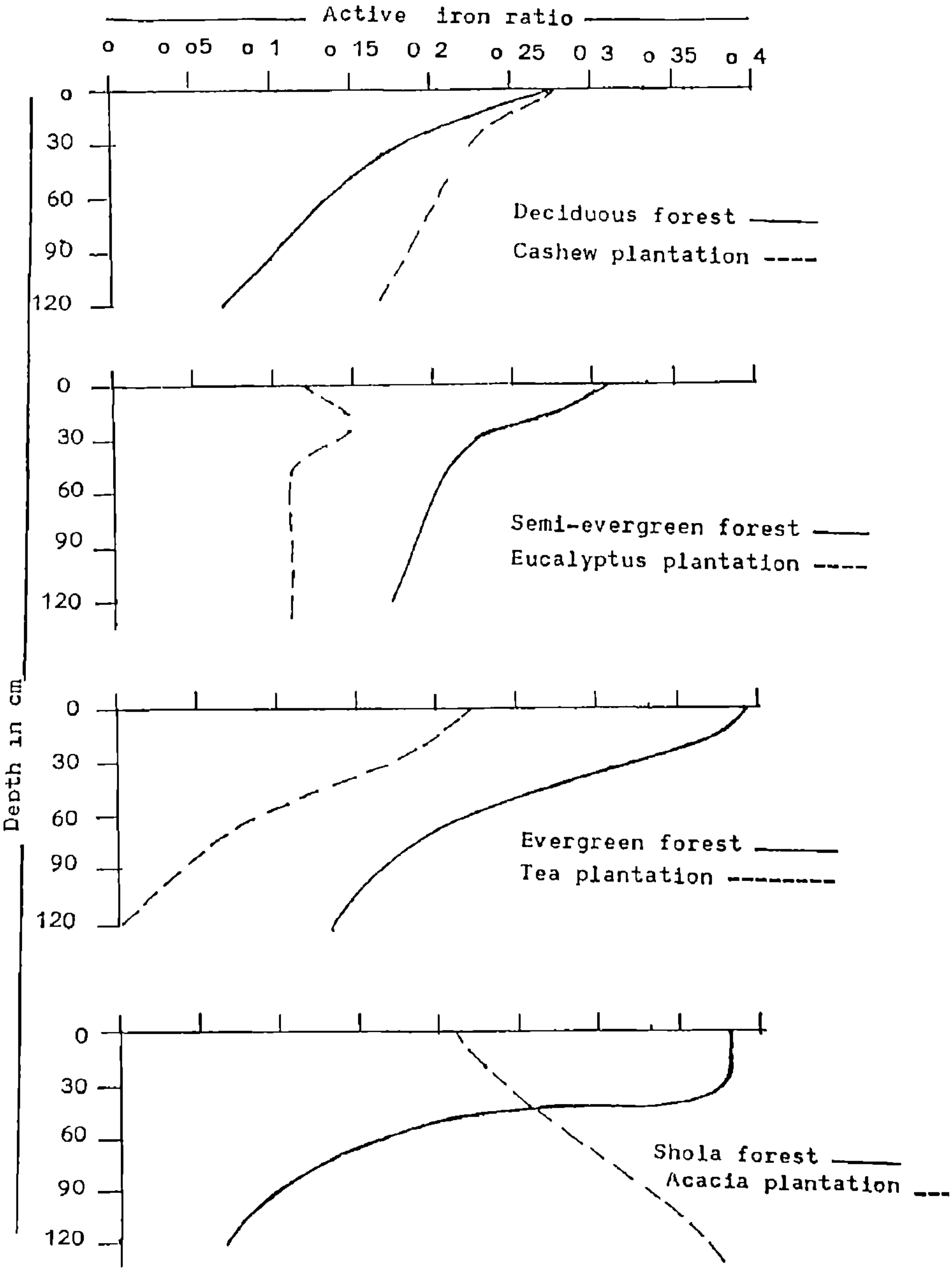

Fig 3 Variation in active iron ratio with depth in different soil profiles

within the deciduous and shola ecosystems. This clearly suggests that the type of planted vegetation has a marked influence on the extent of laterisation in each ecosystem. The present study reveals that the process of laterisation is delayed in deciduous and shola ecosystems by the influence of cashew and acacia respectively while it is favoured in semi-evergreen and evergreen ecosystems by the influence of eucalyptus and tea respectively.

Manganese, zinc and copper

Manganese, zinc and copper are micronutrients which are essential to plant life. The forms and content of these elements are highly variable and related to the leaching environment of the profiles. The content of total manganese is higher in acacia followed by evergreen, shola, deciduous and semi-evergreen. The average content of total manganese is lower in plantation profile, except acacia, compared to the corresponding forest profile. This lowering in the content of manganese in plantation soil compared to the corresponding forest soil might be due to the leaching of this element beyond the depth of the soil profile as a result of deforestation or due to the higher uptake of the element by the plantation crop. The higher accumulation of manganese in the subsurface soil of cashew and acacia might be due to the increased leaching and accumulation at the lowest horizon where a barrier exists to prevent the escape of the element.

Water soluble manganese is found to be practically absent irrespective of the soil. The value of DTPA extractable manganese is found to be higher than that of ammonium acetate extractable manganese(exchangeable). The relatively higher contents of exchangeable and DTPA extractable manganese in the surface soil than in the subsurface soil might be as a result of the soil forming process. The higher content of manganese in the surface soil of forests, attributes to the lesser degree of weathering and ferrallitization in the soil compared to the corresponding plantation soil. A significantly positive correlation is noticed between total manganese and silt/clay ratio(+0.3777*) and a significantly negative correlation between the manganese and clay(-0.4405*). The exchangeable and DTPA extractable manganese is significantly and positively correlated to porespace. The exchangeable manganese is positively and significantly correlated to pH in water(+0.4907*),electrical conductivity (+0.4713) and organic matter(+0.6832**).

The total content of zinc in the forest soil varies from 37.17 to 316.02 $\mu g\ g^{-1}$ while 55.94 to 306.65 $\mu g\ g^{-1}$ in plantation soil. Among the forest profiles, the average content of zinc is highest in semi-evergreen followed by evergreen, deciduous and shola. No regularity is noticed in the downward movement of this element. The average content of total zinc is lower in the tea and eucalyptus plantations while it is higher in acacia and cashew plantations compared to the corresponding forest profiles. At the same time the surface soil of eucalyptus and tea is comparatively richer in zinc than the corresponding forest soil. The variation in zinc content may be due to the effect of deforestation and the influence of the type of plantation vegetation. The water soluble zinc in forest soil ranges from 0.05 to 4.71 μg g^{-1} while trace to 5.75 μg g^{-1} in plantation soil. The concentration of water soluble and DTPA extractable zinc shows no definite pattern of distribution. The concentration of exchangeable zinc extracted by ammonium acetate solution is relatively higher in the upper horizons than in the lower horizons irrespective of the profile. This may be as a result of the soil forming processes. The exchangeable zinc is correlated significantly and positively to silt/clay ratio (+0.4164), pore space(0.4100*), CEC(+0.7052**) and available phosphorus (+0.6137**).

The total content of copper in forest soil is found to range from 17 to 278 μg g^{-1} while 34 to 109 μg g^{-1} in plantation soil. Among the forest profiles, the highest average content of total copper is in evergreen (105) followed by shola (36.8), deciduous (33.25) and semi-evergreen (28.75 μg g^{-1}) . The copper concentration is very low compared to that of manganese and zinc. In most of the profiles investigated, the content of total copper is related to the coarse sand (+0.3659*). The amount of water soluble copper is traceable while the ammonium acetate extractable copper varies from 0.2 to 1.2 $\mu g\ g^{-1}$ of the soil and its distribution is uniform in most of the profiles. In plantation profile, the surface soil generally shows a slightly higher value for exchangeable copper than the subsurface soil which indicates that the plantation soil is more advanced in the soil forming process than the forest soil. The DTPA extractable copper varies from 0.08 to 2.98 $\mu g\ g^{-1}$ of soil and is seen accumulated in the intermediate layers in most profiles. The DTPA extractable copper is significantly and positively correlated to pH in water (+ 0.5943^{**}), pH in KCl (+0.6682^{**}), pH in $CaCl_2$ (0.5966^{**}), electrical conductivity (+0.6444^{**}), available nitrogen (+0.3726^{*}) and available phosphorus (+0.4072^{*}).

The concentrations of manganese, zinc and copper extracted by ammonium acetate are higher in the upper horizons than in the lower horizons in most of the profiles studied. This observation is in conformity with the findings of Smirnova and Motuzova (1985) and they attributed this to the soil forming process.

Mineralogy

The mineralogy of fine sand fraction of the soils under study is given in Tables 13, 14.1, 14.2, 14.3 and 14.4.

The heavy mineral fraction varies from 2.5 to 27.60 per cent of the fine sand and is seen accumulated more in the upper horizons than in the lower horizons. The heavy mineral fraction consists of black opaque, zircon, Kyanite, rutile, leucoxene, amphibole, tourmaline, monozite, chlorite, garnet, titanite and spinel of which the dominant ones are black opaque, sillimanite, red opaque and zircon. The light mineral fraction constitutes mainly of quartz with small amounts of feldspars and micas. But in the lowest horizon of shola forest mica is the dominant mineral. It is evident from the data that the light fraction mineral is distributed relatively more in the lower layers than the upper ones. In all the soils, the values of heavy mineral fraction are much less compared to the light mineral fraction. The grains vary in size from 30 to 200 micron and have angular to subangular and sub rounded shapes. A close examination of the type, content and distribution of these minerals suggests that the soils are likely to be formed from the same parent material namely granite gneiss.

The profiles from deciduous and semi-evergreen ecosystems and acacia plantation have a sequence of black opaque - sillimanite- red opaque- zircon while those from evergreen ecosystem and shola forest have the sequence of silliminite-black opaque - red opaque- zircon with respect to heavy minerals. The heavy minerals appear to be more in plantation profile (3.7 to 27.6 per cent of the fine sand) than in the forest profile (2.5 to 19.5 per cent of fine sand).

The amount of quartz ranges from 22.6 to 97.5 per cent of the fine sand which indicates that quartz is the predominant fine sand mineral. Subramonia Iyer (1979) has observed that quartz is the dominant fine sand fraction in laterite and red soils of Kerala. The average content of quartz fraction in fine sand is found to be a little high in most forest soils compared to the corresponding plantation soil. No definite pattern is observed for the distribution of quartz. At the same time distribution of other resistant minerals like zircon and tourmaline show a decrease with depth. The content of weatherable minerals such as feldspars, micas and chlorite are found to increase with depth irrespective of the profile. Chakravarthy (1979) attributed this to the higher rate of surface weathering. This observation also suggest that the soils are young and are at a higher stage of pedogenic development. The occurrance of weatherable minerals indicates the low degree of weathering(Subbiah and Manickom, 1985). Among the forest profiles the amount of weatherable minerals is highest in shola followed by semi-evergreen, evergreen and deciduous. The content of weatherable minerals is found to be more in cashew and acacia soils while lesser in eucalyptus and tea soils compared to the corresponding forest soils. This observation clearly indicates that while eucalyptus and tea hasten the intensity of weathering of the soil, cashew and acacia delay the process of weathering compared to that of the corresponding forest vegetation.

Micromorphology

The study of thin sections reveals that the nodules in the middle horizons of all the soil profiles are intact and stable whereas those from the surface horizons are apparently dissolving leaving quartz rich grains protruding from the iron rich matrix. Similar observation has been reported in southern Rhodesia and parts of Australia by Sivarajasingham et al (1962).

Harrison (1933) found that igneous rocks of the tropics with free drainage is accompanied by the complete removal of silicon, calcium, magnesium, potassium and sodium leaving an earthy residue of gibbsite, limonite, a few unaltered fragments of fieldspars, secondary quartz and the various resistant minerals 'the primary laterite'. The conversion of ferrous to ferric iron can be seen in all the thin sections as a characteristic change in colour and staining of the rock fragments with iron oxides (Plates No. 18 to 68).

Under the microscope it can also be seen that feldspar laths of original rock have been replaced by gibbsite which are embedded in a reddish brown mass having the appearance of fine grained clay stained by iron (semi-evergreen, Plate No.33). When observed from the bottom to the surface of the profile, opaque minerals present are appeared to be slightly more irrespective of the location. The microprocesses suggest that solution of gibbsite and its combination with silica in solution form Kaolin in the laterising layers.

Weathering of biotite and plagioclase feldspars are seemingly operative in the surface soils than in the sub-surface soils which indicates that the degree of weathering is low in the subsurface soils. The occurrance of the weatherable mineral is found to be more in the shola soil (Plates No. 56 to 63). Among the plantation soils it is more in the cashew (Plates No. 25 and 28) and less in Eucalyptus (Plates No. 36 to 40). Irrespective of the profiles Kaolinization and coincident weathering of the primary minerals are apparently not complete in the upper horizons. No gibbsite is observed in this region. From the above observations it is inferred that Kaolinization proceeded directly from the primary minerals or that resilication, if it occurred, proceeded concurrently with the disruptionof the primary minerals.

The study of the thin sections and single grain analysis further reveal that the character and distribution of quartz indicates the residual origin of the profiles irrespective of the vegetation. The quartz grains in the upper layers of cashew, semi-evergreen, eucalyptus, tea and acacia profiles are seen placed closely than in the lower layers suggesting loss of values upwards. Considering the large part of the SiO_2 is quartz some mechanism as external enrichment of iron or of a discontinuity in the profiles is probable.

Iron is seen mobilized to a greater degree and greater depth in the deciduous, cashew, semi-evergreen, eucalyptus, tea and shola profiles. The condition of high acidity, presence of reducing agents and presence of chelating agents might be responsible for the increased mobilization.

Large part of the thin sections of the lateritic horizons irrespective of the profile are composed of nets of small flakes oriented iron stained clay. The sections contain more quartz per unit area than the deeper material and this, with the discontinuity of clay nets and clay skins, suggest some break down of kaolin accompanied by loss of volume and release of iron that had been observed on clays. Some red highly birefringent pore linings, crack fillings, and other spots observed in the laterite horizon of semi-evergreen are goethite (Plate No.34).

In the soils under evergreen forest, the materials required for laterite genesis namely iron is present in smaller amount compared to the other soils. The evergreen soil is coarse textured throughout while others have a fine texture. The small specific surface of the coarse textured soil to take up iron as coatings might be the reason for the expression of the above character.

SUMMARY AND CONCLUSIONS

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With regard to geology, geomorphology and climate, the forested regions of Kerala fall within the limits conducive for laterization. Continuous denudation of forest along the Western Ghats region has brought about hastening of the process of laterization. Deforestation and subsequent hardening of the soil has become a constraint to agricultural development. Important types of forests found in the State are deciduous, semi-evergreen, evergreen and shola. Deforestation of these different types of forests may bring about laterisation to different extent. Deforestation and monoculture with different economically important tree species and plantation crops such as eucalyptus, acacia, tea and cashew may delay or hasten the process of laterisation to varying extent. The subsequent changes brought about in the soil properties have not been evaluated in any published work. The present study is, therefore, to understand more about the effect of different monoculture vegetations such as cashew, eucalyptus, tea and acacia on soil properties in comparison with the soils of adjoining virgin soils in deciduous, semi-evergreen, evergreen and shola forest ecosystems respectively. With this objective, detailed field and laboratory studies, including that of the mineralogy and the micromorphology, have been conducted on eight representative soil profiles from four different forest ecosystems.

Some of the salient observations from these studies are presented below:

1. Geologically all the soils from the eight locations representing the four different ecosystems are developed from the same parent material namely granite gneiss of Archaean age. The uniformity of the parent material of all the profiles is evident to a reasonable certainty on the basis of the particle size analysis, bulk density, soil colour and the types and distribution of fine sand minerals.

2. The profiles representing the semi-evergreen and deciduous ecosystems are located at lower altitudes while that of evergreen and shola ecosystems are located at higher altitudes. Though the soils are exposed to different climate, mainly due to the manifestation of altitude, all the locations fall within the limits with regard to geology, geomorphology and climate conducive for ferrallitization.

3. The soils under natural forests, irrespective of the ecosystems are not subject to severe movements and, therefore, retain the juvenile nature, whereas the soils from planted forests are found to be in a more senile state.

4. The laterization index of the locations coming under deciduous and semi-evergreen ecosystems is 32.1 while that of the locations coming under evergreen and shola ecosystems is 36.8. Inspite of the high rainfall the low L

value observed at the higher altitudes is due to the modifying effect of the low mean minimum temperature.

5. The difference in the canopy structure and the litter layer on the floor owing to different types of vegetation influence the microclimate, moisture status and erodability of the soils to varying extent. The decomposition of organic matter is found to be more in soils under planted vegetation and deciduous forest than under evergreen and shola forests.

6. The increased root activity exhibited by tea and acacia helps tham to withdraw nutrients from the lower illuvial zones where illuvial nutrients are accumulated. Moreover, the deep penetration and binding action of their roots have strengthened the structural stability and improved the single value constants such as low bulk density, higher porosity and water holding capacity of the subsurface soil under these two plantations (tea and acacia) compared to others including natural vegetation.

7. Acacia can enrich the nitrogen status of the soil at a faster rate by its ability to fix atmospheric nitrogen.

8. The colour of the surface soil, irrespective of the vegetation, is dark brown or dark grey due to the different soil content of humified organic matter. These colours also indicate that the soil is mostly uneroded. The yellowish red or yellow colours of the subsurface soil are due to the difference in the status of hydration of iron oxides. The dark red or reddish brown colours of the subsurface soil at the semi-evergreen, tea and acacia locations indicate that the soil is well aerated and rich in iron and ironoxides. These colours are also characteristic of intense weathering of the soil.

9. The proportion of gravel is significantly higher in all the eight locations. In forest soil gravel content is more in the subsurface soil, whereas in plantation soil it is found more in the surface.

10. The content of coarse sand is higher in forest soil than that in the corresponding plantation soil in all the ecosystems. In most of the forest soils sand content increases with depth while in the plantation soils it decreases with depth. It indicates that laterisation is advanced as a result of deforestation.

11. The proportion of the silt content is more in the surface soil than in the subsurface soil irrespective of the location.

12. The clay content in the forest soils varies from 11.8 to 36.19 per cent while in the plantation soils it ranges from 10.79 to 43.59 per cent. In most of the forest profiles clay content increases with depth upto an intermediate layer and then decreases, whereas, in the plantation profiles it increases uniformly with depth. The progressive decline in the content of sand fraction and a corresponding increase in the content of clay fraction with depth noticed in the plantation profiles as compared to the forest profiles indicate the fact that deforestation causes mechanical elluviation with a higher migration of clay colloids from surface downwards.

13. Among the forest soils, the highest content of average clay is observed in deciduous (28.85%) followed by semi-evergreen(21.32%), shola (19.43%) and evergreen (16.12%) which indicates that weathering and clay formation is more in deciduous forest than in other forests.

14. A higher content of clay in eucalyptus and tea soils and a lower content in cashew and acacia soils compared to the corresponding forest soils indicate that influence of tea and eucalyptus hastens the process of weathering while that of cashew and acacia appears to delay the process.

15. A higher silt/clay ratio registered in the diagnostic horizons of all the investigated profiles indicates a lower degree of ferrallitization of the soil.

Based on the ratio, the soils can be arranged in the following order according to the observable factors on the degree of weathering: eucalyptus > tea > deciduous semi-evergreen > cashew > shola > evergreen > acacia.

16. The bulk density of the surface soil under plantations is comparatively higher than that under forests. The low organic matter content and the sandy nature of the soil together with the less stable structure might have been contributed in addition to the clear felling operations and subsequent land preparation in increasing the bulk density of the surface soil in the plantation sites.

17. The porosity and the maximum water holding capacity are relatively higher in the surface soil than in the subsurface soil in most of the profiles investigated. The average values for porosity and maximum water holding capacity are lower for the cashew and eucalyptus soils while higher for tea and acacia soils when compared to their corresponding forest soils. The unusual trend observed in tea and acacia soils with respect to porosity and water holding capacity might be largely due to their increased root activity preferably in the subsurface soil.

18. The comparatively low volume expansion of the soils, irrespective of the location, attributes the

presence of non-expanding type of colloidal material a unique character of laterite soils.

19. The percentage soil aggregates and the mean weight diameters for the forest soils are higher than that for the corresponding plantation soils in most ecosystems. The water stable aggregates are relatively higher in the surface soil than in the subsurface in all the forest soils whereas a reverse trend is noticed in its distribution in all the plantation soils.

20. In general, the forest soils are slightly more acidic than the corresponding plantation soils except in the case of eucalyptus soil which records a lower pH than the corresponding semi-evergreen forest soil. Among the forest soils deciduous forests record the lowest pH value.

21. The investigation reveals that the tea soil is weakly acidic, the semi-evergreen, evergreen, cashew and acacia soils are medium acidic while deciduous, eucalyptus and shola soils are strongly acidic. The low acidity of the tea soil can be attributed to the presence of higher content of bases such as calcium (1070 $\mu g\ g^{-1}$) and magnesium (4467 $\mu g\ g^{-1}$ of soil) due to the regular application of fertilizer containing the bases and continuous biocycling of the bases occurs in the soil.

22. Irrespective of the location, the surface soil is generally less acidic than the subsurface soil. This condition tends to prevail in soils that support the type of vegetation whose foliage contains a higher content of bases.

23. The pH in 1 N sodium fluoride registers an increase by 2.7 to 6.4 units in forest soil while 1.6 to 6.6 units in plantation soil compared to that obtained in distilled water. This indicates that the soils have a net positive charge due to the dominance of the exchangeable complex by hydrous iron and aluminium oxides. The cashew soil shows the maximum increase of 6.6 units while the minimum of 1.6 unit is shown by the tea soil.

24. The pH in 1 N potassium chloride solution is found to be lower for all the soils compared to that in distilled water, the lowering being in the range of 0.1 to 0.7 units. The minimum lowering of the pH in KCl in cashew and tea soil (0.1 unit) might be due to the low exchangeable acidity of the soil while the maximum lowering of the pH in KCl (0.7 unit) noticed in evergreen forest soil indicates a higher exchangeable acidity of the soil compared to the others.

25. The pH of the soils in 0.01 M calcium chloride solution shows a reduction of 0.2 (cashew) to 0.7 (semi-evergreen forest) unit than that in distilled water.

26. The electrical conductivity of the tea soil is significantly higher indicating that the soil is abundant in soluble salts. Irrespective of the location, the electrical conductivity is found to decrease with depth which indicates that water soluble salts are predominant in the surface soil than in the subsurface.

27. Inspite of the low clay content, the relatively higher CEC observed for the surface soil reveals that the CEC is mostly contributed by the organic matter. The low CEC generally observed in all the soils indicates that the clay is of a non-expanding type.

28. Irrespective of the location, the surface soil shows a higher content of organic matter which steadily decreases with depth.

29. With regard to the organic carbon, the highest value recorded is in the soil under deciduous forest (3.05%). The organic carbon content of the plantation soil generally shows a comparatively lower value for the surface soil and a higher value for the

sub-surface soil compared to that of the corresponding forest soil. This indicates that the organic carbon has been partly leached off and eroded off and partly burnt faster due to denudation.

30. Ferrallitization advances in shola forest even if the level of organic matter in the surface soil is 5.19 per cent while significant ferrallitization has not been observed in acacia plantation having only 4.07 per cent organic matter in the surface soil through both the soils fall under the same ecosystem. The intricacies of the role played by different types of vegetation in the manifestation of laterisation are yet to be explored and the extent of laterisation, therefore cannot be discussed merely on the basis of the level of the organic matter alone.

31. Based on the content of total nitrogen, the forest soils can be arranged in the order: deciduous > evergreen > semi-evergreen and shola. The content of total nitrogen is comparatively higher in most of the plantation soils than that in the corresponding forest soils.

32. While acacia and cashew soil register a higher value in the content of average total nitrogen, the value recorded for the average available nitrogen

is the lower one. Mean while the shola soil which records the lowest content of total nitrogen registers the highest value in the content of available nitrogen. It appears that the nitrogen mineralisation is at a faster rate in eucalyptus and tea soil compared to other soils.

33. The subsurface soil under the plantations is characterised by the presence of comparatively higher concentration of total and available nitrogen than that of the corresponding forest soil which indicates that decomposition and mineralisation of organic matter and leaching to a lower depth have been taken place at an increased rate in plantation sites immediately after the clear felling.

34. The surface soil from the natural forest shows a higher C/N ratio than the corresponding plantation soil. It indicates that accumulation of undecomposed organic matter is relatively higher in forest soil while the process of decomposition is quite rapid in plantation soil.

35. The total content of phosphorus in forest soil ranges from 0.031 to 0.171 per cent while in plantation soil it ranges from 0.039 to 0.213 per cent.

Among the forest soils shola recorded the highest value of average total phosphorus followed by semi-evergreen , evergreen and deciduous.

36. With regard to the content of the total phosphorus a slight increase is observed in all the plantation soils than the corresponding forest soils. Phosphorus is generally seen accumulated in the middle horizons of the forest profile whereas in plantation profile its distribution shows no definite pattern.

37. The available phosphorus status of the soils irrespective of the location is poor and varies from trace to 17.1 $\mu g\ g^{-1}$ of the soil.

38. In older plantations as well as in natural forests potassium is found to concentrate in the surface soil as it is rapidly and efficiently phytocycled and very little potassium is appeared to be leached downwards. In soils under younger plantations potassium is accumulated more in the lower layer due to the increased leaching of the element following deforestation.

39. Among the forest soils, the semi-evergreen shows the highest content of average total potassium followed by shola, deciduous and evergreen. The gradient

of the potassium content among the forest soils can be related to the potassium bearing minerals such as mica, feldspar etc. present in the soils. No significant difference is observed in the average content of total and available potassium between forest and plantation soils within each ecosystem.

40. The average content of calcium is lower in the plantation soil, except tea soil compared to the corresponding forest soil. The higher content of calcium observed in tea soil might be due to the regular application of fertilizers containing this element.

41. In most of the locations calcium and magnesium are found accumulated in the upper horizons than in the lower horizons.

42. The plantation soils, in general, contain comparatively higher amounts of average total iron and aluminium than the corresponding forest soils in all the ecosystems. The iron and aluminium content of the soil is found to increase with depth in most of the profiles which is an expression of the juvenile nature of the soil.

43. A higher proportion of aluminium noticed in all the soils with respect to iron places the soils under the category of ferrallitic soils.

44. A highly significant positive correlation exists between clay and aluminium (+0.5528) indicates that aluminium released during the course of weathering might pass into the clay minerals.

45. The water soluble iron varies from trace to 14 $\mu g\ g^{-1}$ in forest soils while in plantation soils it ranges from trace to 50 $\mu g\ g^{-1}$ of soil. Irrespective of the location the maximum content of this form of iron tends to concentrate in the upper and middle horizons leaving only a trace in the lowest horizon. It is strongly and positively correlated to pH in water (+ 0.7207), calcium (+0.6353) and magnesium (+0.5407).

46. The ammonium extractable (exchangeable) iron varies from 28 to 154 $\mu g\ g^{-1}$ of forest soil whereas 24 to 192 $\mu g\ g^{-1}$ in plantation soil. The DTPA extractable iron ranges from 3 to 439 $\mu g\ g^{-1}$ and from trace to 456 $\mu g\ g^{-1}$ in forest and plantation soils respectively. Irrespective of the location, distribution of these forms of iron shows a steady decrease with depth. The average content of these forms of iron is relatively high in plantation soil than in forest soil.

47. The water soluble and the DTPA extractable aluminium are more in the surface soil than in the subsurface soil. No definite pattern is evident in the distribution of the exchangeable aluminium.

48. Irrespective of the location, the dithionite extractable iron ($Fe_{(d)}$) increases with depth. The content of $Fe_{(d)}$ varies from 5480 to 25440 $\mu g\ g^{-1}$ in forest soil while 11480 to 31160 $\mu g\ g^{-1}$ in plantation soil. The $Fe_{(d)}$ is significantly and positively correlated to clay (+0.4607) and negatively to organic matter (-0.4697). It confirms the fact that the iron moves along with clay colloidal fractions down the profile at all the locations.

49. The oxalate extractable iron is present in small quantities compared to the dithionite extractable iron which reveals that in well drained soils iron remains mostly in the crystalline form.

50. The higher active iron ratio observed in the surface soils of the natural forests compared to that of the plantations explains the relative juvenile nature of the forest soils. The ratio is correlated significantly and positively to organic matter (+0.5681) and negatively to clay (-0.6486) which indicates the inhibitory effect of organic matter in the crystallisation of iron.

51. The average value of active iron ratio is found higher in forest soil than in the plantation soil within the semi-evergreen and evergreen ecosystems while a reverse trend is noticed within the deciduous and snola ecosystems. This clearly suggests that the type of planted vegetation has a marked influence on the extent of laterisation in each ecosystem. The present study reveals that while cashew and acacia delay the process of laterisation in deciduous and shola ecosystem respectively eucalyptus and tea favour the process in semi-evergreen and evergreen ecosystems respectively.

52. The concentration of manganese is very low in the plantation soils compared to the corresponding forest soils which can be attributed to the leaching of the element beyond the depth of the soil profile as a result of deforestation. The higher content of manganese in the surface soil of forest compared to that of the corresponding plantation indicates the lesser degree of weathering and ferrallitization in forest soil.

53. The concentration of DTPA extractable and ammonium accetate extractable manganese is found more in the surface soil than in the subsurface soil irrespective of the location .

54. The total content of zinc in the forest soil varies from 37.17 to 316.02 $\mu g\ g^{-1}$ while 58.94 to 306.65 $\mu g\ g^{-1}$ in the plantation soil. Water soluble zinc in the forest soil ranges from 0.05 to 4.71 $\mu g\ g^{-1}$ while 0.29 to 5.75 $\mu g\ g^{-1}$ in the plantation soil. No regularity is noticed in the distribution of the element down the profile.

55. The concentration of copper in the forest soil ranges from 17 to 278 $\mu g\ g^{-1}$ while 34 to 109 $\mu g\ g^{-1}$ in the plantation soil. The concentration of copper is very low compared to that of the manganese and zinc. The amount of water soluble copper is traceable to detect. Exchangeable (ammonium acetate extractable) copper varies from 0.08 to 2.98 $\mu g\ g^{-1}$ of soil and is seen accumulated in the intermediate layers of the most of the investigated soil profiles.

56. The heavy mineral fraction varies from 2.5 to 27.6 per cent of the fine sand fraction. It is found accumulated more in the upper horizons than in the lower horizons. The dominant heavy minerals are black opaque, sillimanite, red opaque and zircon. The light mineral fraction constitutes mainly of quartz (22.6 to 97.5%) with small amounts of feldspars and micas. In all the soils, the heavy mineral fraction is much less

compared to the light mineral fraction. The heavy mineral fraction is comparatively higher in the plantation soils than in the corresponding forest soils.

57. The distribution of resistant minerals such as zircon and tourmaline shows a decrease with depth while weatherable minerals like feldspar, mica and chlorite are found to increase with depth irrespective of the location. This can be attributed to the higher surface weathering and the soils are at a stage of pedogenic development.

58. The weatherable minerals are found more in cashew and acacia soils and lesser in eucalyptus and tea soils compared to the corresponding forest soils. This clearly indicates that while eucalyptus and tea hasten the process of weathering of the soil, cashew and acacia delay the process when compared to the corresponding forest vegetation.

59. The thin section microscopy of the different profiles reveals that the lateritic nodules in the sub-surface soil are intact and stable, whereas those in the surface soil are left with iron rich matrix and

quartz grains embedded in the matrix. Conversion of ferrous to ferric iron is an another observation of the thin section study of the soils. The opaque minerals decrease down the profile at all the locations. The micro-pedogenesis of Kaolinite from gibbsite and silica in solution is clearly noticeable in the laterised layers of the profiles. The effects of vegetation and phytocycling are observed as micro and macro aggregates of the humus alone and in combination with ferrous iron. The character and distribution of quartz indicate the residual origin of the soil irrespective of the location.

60. Iron is seen mobilized to a greater degree and depth in the deciduous, cashew, semi-evergreen, eucalyptus, tea and shola profiles. All the soils are laterised with developing argillic horizons and clay skins.

The present studies based on soils of monoculture plantation crops such as cashew, eucalyptus, tea and acacia in comparison to virgin soils, enough evidences are available to show that planted forests/ plantation crops favour laterisation in general. Among the various types of monoculture, eucalyptus enhances laterisation to the greatest extent while cashew and acacia favour laterisation to the least extent.

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* Original not seen.

APPENDICES

APPENDIX-I

Profile No.1	DECIDUOUS FOREST

Classification

Soil Name	Kottur Kallar association
Higher category	Hapludolls
Date of examination	10-2-1988
Author	N.SIVADASAN

Site

Location	Half-a- Kilometer NW of Anappara forest guard station on Anappara-Vamanapuram irrigation project road, Vithura Village, Nedumangadu Taluk, Trivandrum District.
Latitude	8°41' and 8°42' North
Longitude	77°6' and 77°7' East
Elevation	230 m above M.S.L.
Landform	Middle slope of a mid upland hill; gently slopy microtopography; surroundings have a rolling topography.
Slope	18% SW. Nearly straight along the slope and slightly convex across.
Vegetation	Natural forest with less dense canopy

General Information

Parent material	Granite gneiss
Drainage	Well drained, no stagnant water after heavy rains.

Appendix-I (contd.)

Moisture	Moist throughout
Ground water	Deeper than 7 m at time of observation.
Presence of surface stone.	No
Evidence of erosion	Sheet and gully
Presence of salt or alkali.	No
Climate	Hot humid tropical with mean annual rainfall of 2177 mm and mean temperature ranges from 21.9°C to 32.6°C

APPENDIX - II

Profile No.2	CASHEW PLANTATION
<u>Classification</u>	
Soil Name	Kottur Kallar association
Higher category	Hapludolls
Date of examination	10-2-1988
Author	N. SIVADASAN
<u>Site</u>	
Location	50 m NW of Anappara Forest Guard Station 5 km from Vithura on Trivandrum Ponmudi Road, Vithura Village, Nedumangadu Taluk, Trivandrum District.
Latitude	$8^{\circ}41'$ and $8^{\circ}42'$ North
Longitude	$77^{\circ}6'$ and $77^{\circ}7'$ East
Elevation	230 MSL
Landform	Middle-slope of a mid upland hill; gently sloping microtopography, surroundings have a rolling topography.
Slope	15% SW. Nearly straight along the slope and slightly convex across.
Vegetation	Deforested and cultivated mainly with cashew.

Appendix- II (contd.)

General Information

Parent material	Granite gneiss
Drainage	Well drained; no stagnant water after heavy rains.
Moisture	Moist throughout
Groundwater	Deeper than 7 m at the time of observation.
Presence of Surface stone.	No
Evidence of erosion	Sheet and rill
Presence of salt/ alkali	No
Climate	Hot humid tropical with mean annual rainfall of 2177 mm and mean temperature ranges from 21.9^{9}C to 32.6^{o}C

APPENDIX- III

Profile No. 3	SEMI-EVERGREEN FOREST

Classification

Soil Name	Kottur Kallar association
Higher category	Hapludolls
Date of examination	10-2-1988
Author	N. SIVADASAN

Site

Location	Thalathootha, 2.5 km NW of Anappara, Vithura Village, Nedumangadu Taluk, Trivandrum District.
Latitude	$8^{\circ}42'$ and $8^{\circ}43'$ North
Longitude	$77^{\circ}6'$ East
Elevation	200 m above MSL
Land form	Lower part of a gently sloping upland hill to valley; microtopography is gently slopy; surroundings have undulating topography.
Slope	8% SW slightly concave along the slope and almost straight across
Vegetation	Natural forest with moderately dense canopy

General Information

Parent material	Granite Gneiss

Drainage	Well drained, no stagnant water after heavy rains
Moisture	Moist throughout
Ground water	4 m deeper at the time of observation.
Presence of surface stone.	No
Evidence of erosion	Sheet and rill
Presence of salt/ alkali	No
Climate	Hot humid tropical with mean annual rainfall of 2177 mm and mean temperature ranges from 21.9°C to 32.6°C.

APPENDIX IV

Profile No.4	EUCALYPTUS PLANTATION

Classification

Soil Name	Kottur Kallur association
Higher category	Hapludolls
Date of examination	10-2-1988
Author	N. SIVADASAN

Site

Location	Thalathootha, 2.5 Km NW of Anappara Vithura village, Nedumangadu Taluk, Trivandrum District.
Latitude	$8^{\circ}42'$ and $8^{\circ}43'$ North
Longitude	$77^{\circ}6'$ East
Elevation	200 m above M.S.L.
Land form	Lower slope of upland hill to a valley, surroundings have undulating topography; microtopography is gently sloping
Slope	10% SW slightly convex along and across the slope
Vegetation	Deforested and subsequently planted with Eucalyptus.

Appendix IV (contd.)

General Information

Parent material	Granite, gneiss
Drainage	Well drained with moderately slow internal permeability
Moisture	Moist throughout
Ground water	About 4 m deep at the time of observation.
Presence of surface stone.	No
Evidence of erosion	Sheet and rill
Presence of salt/ alkali	No
Climate	Hot humid tropical with mean annual rainfall of 2177 mm and mean temperature ranges from 21.9°C to 32.6°C.

APPENDIX - V

Profile No.5	EVERGREEN FOREST

Classification

Soil Name	Kottur Kallar association
Higher category	Hapludolls
Date of Examination	9-2-1988
Author	N. SIVADASAN

Site

Location	About 6 km away fro[illegible] [illegible] [illegible] [illegible] 10th hair pin curve, on Trivandrum - Ponmudi road; Thennoor Village, Nedumangadu Taluk, Trivandrum Dist.
Latitute	$8^{\circ}44'$ and $8^{\circ}45'$ North
Longitude	$77^{\circ}7'$ and $77^{\circ}8'$ East
Elevation	650 m above MSL
Land form	Middle slope of a high land steep hill; microtopography sloping; surroundings have a rolling topography with steep hills.
Slope	50% facing SW, almost straight along the slope but slightly convex across.
Vegetation	Natural forest, fully stocked with dense canopy.

Appendix- V (contd.)

General Information

Parent material	Granite gneiss
Drainage	Well drained, moderately rapid permeable, no stagnant water after heavy rains.
Moisture	Moist throughout
Ground water	6 m at the time of observation
Presence of surface stone	No
Evidence of erosion	Sheet and rill
Presnece of salt/alkali	No
Climate	Humid tropical. 75 years of meteorological data shows a mean annual rainfall of 4184 mm with 159 rainy days. Mean temperature ranges from 19.3°C to 29.4°C.

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APPENDIX - VI

Profile No.6	TEA PLANTATION
Classification	
Soil name	Kottur Kallar association
Higher category	Hapludolls
Date of examination	9-2-1988
Author	N. SIVADASAN
Site	
Location	Merchiston Tea estate. 7.2 km from Vithura on Trivandrum- Ponmudi Road; Thennoor Village, Nedumangadu Taluk, Trivandrum District.
Latitude	8°44' and 8°45' North
Longitude	77°7' and 77°8' East
Elevation	665 m above MSL
Land form	Middle slope of a high land hill. Microtopography - sloping; surroundings have a rolling topography with steep hills.
Slope	40% SE, almost straight along the slope but slightly convex across.
Vegetation	Tea plantation

Appendix- VI (contd.)

General Information

Parent material	Granite gneiss
Drainage	Well drained; no stagnant water after heavy rains
Moisture	Moist throughout
Ground water	6 m at the time of observation
Presence of surface stone.	No
Evidence of erosion	Sheet and rill
Presence of salt/ alkali	No
Climate	Humid tropical with mean annual rainfall of 4184 mm and mean temperature ranges from 19.3°C to 29.4°C.

APPENDIX - VII

Profile No. 7	SHOLA FOREST

Classification

Soil Name	Kottur Kallar association
Higher category	Hapludolls
Date of examination	8-2-1988
Author	N. SIVADASAN

Site

Location	Ponmudi top. About 50 m behind Deer park, Thennoor Village, Nedumangadu Taluk, Trivandrum District.
Latitude	8°45' and 8°46' North
Longitude	77°6' and 77°7' East
Elevation	1030 m above MSL
Land form	Upper slope of a gently sloping high land hill; microtopography - gently sloping; surroundings have undulating rolling topography with hills.
Slope	12% S slightly convex across and along the slope.
Vegetation	Natural forest, fully stocked with dense canopy.

(Appendix VII (contd.)

General Information

Parent material	Granite gneiss
Drainage	Well drained, no stagnant water after heavy rains
Moisture	Moist throughout
Ground water	4 m at the time of observation
Presence of surface stone	Scarce at profile site but plenty in surroundings.
Evidence of erosion	Sheet and rill
Presence of salt/ alkali	No
Climate	Humid tropical with mean annual rainfall of 4184 mm and mean temperature ranges from $19.3^{\circ}C$ to $29.4^{\circ}C$.

APPENDIX- VIII

Profile No.8	ACACIA PLANTATION

Classification

Soil Name	Kottur Kallar association
Higher category	Hapludolls
Date of examination	8-2-1988
Author	N. SIVADASAN

Site

Location	Ponmudi top. About 500 m from Dear Park on Ponmudi-Trivandrum Road, Thennoor village, Nedumangad Taluk, Trivandrum District.
Latitude	$8^{\circ}45'$ and $8^{\circ}46'$ North
Longitude	$77^{\circ}6'$ and $77^{\circ}7'$ East
Elevation	1020 m above MSL
Land form	Upper slope of a gently sloping highland hill; microtopography - gently sloping; surroundings have undulating rolling topography with hills.
Slope	10% SW slightly concave along and convex across the slope
Vegetation	Acacia plantation

General Information

Parent material	Granite gneiss
Drainage	Well drained; no stagnant water after heavy rains
Moisture	Moist throughout
Groundwater	4 m at the time of observation
Presence of surface stone	Hard laterite out crops plenty in the surroundings
Evidence of erosion	Sheet and gully
Presence of salt/ alkali	No
Climate	Humid tropical with mean annual rainfall of 4184 mm and mean temperature ranges from 19.3°C to 29.4°C.

APPENDIX IX (1)

Correlation between soil properties

	Clay	Silt/ clay ratio	Pore space	Percentage aggregate	Electrical conductivity	CEC	pH (in D water)	Organic carbon	Organic matter	Total iron
Volume expansion	0 4996**	0 0187	0 1171	0 2042	-0 0396	0 5234**	-0 4113*	0 0243	-0 0324	0 1997
Organic matter	-0 4456*	0 6083**	0 4902**	0 3663*	0 6023**	0 3794*	0 3456	0 997**	1 000	-0 204
Total nitrogen	-0 4762**	0 6403**	0 5216**	0 3523	0 6112**	0 3695*	0 4118*	0 9684**	0 9638**	-0 0316
Available potassium	-0 4447*	0 4556*	0 2416	0 1525	0 5707**	0 1833	0 4486*	0 5046**	0 5072**	-0 4082*
DTPA extractable Iron	-0 4382*	0 7152**	0 3016	0 4380*	0 2609	0 4540*	0 0815	0 6820**	0 6800**	0 0031
Dithionite extractable Iron	0 4607*	-0 2480	0 1087	-0 0631	-0 4032*	0 0262	-0 3346	0 4599*	0 4697**	0 7355**
Oxalate extractable Iron	0 2037	0 3202	0 2920	0 1338	-0 230	0 0221	-0 1757	0 0219	0 0385	0 3835*
Active iron ratio	-0 6486**	0 6 63**	0 4387*	0 2690	0 1646	0 0934	0 0654	0 5777**	0 5681**	-0 3036
Total aluminium	0 5528**	0 3765*	0 2441	0 0773	-0 4910*	0 0919	-0 3895*	0 5276**	-0 5156**	0 6584**
Water soluble aluminium	-0 1224	0 0322	0 1947	0 0953	0 6124**	0 1942	0 5333**	0 4888**	0 4903**	-0 1611
DTPA extractable aluminium	-0 2938	0 5018**	0 2926	0 3914*	0 2518	0 5590**	0 0270	0 5353**	0 5361**	0 1173
Total manganese	-0 4405*	0 3777*	0 3506	0 1928	-0 0248	0 1780	0 1438	0 1158	0 1127	0 0627
Exchangeable manganese	-0 4535*	0 4618*	0 4139*	0 2411	0 4713*	0 0895	0 4907**	0 6856**	0 6832**	-0 1275
DTPA extractable manganese	-0 2432	0 4109*	0 4782**	0 2985	0 1841	0 2502	-0 0321	0 3384	0 3378	0 0087
Exchangeable zinc	-0 5207**	0 4164*	0 4100*	0 0137	0 7052**	0 0337	0 7613**	0 6941**	0 6928**	-0 2650

r_{27} 05 0 3652

r_{27} 01 – 0 4678

* Significant at 5 per cent level

** Significant at 1 per cent level

Appendix - IX (ii)

Correlation between soil properties

	Coarse sand	Available phosphorus	Total potassium	Total Iron	Water soluble iron	Exchangeable zinc	DTPA extractable copper
pH (in D water)	0 1151	0 8488**	-0 1512	-0 0968	0 7207**	0 7613**	0 5943**
pH (in 1 NKCl	0 0191	0 8384**	-0 1467	0 0297	0 7006**	0 6058**	0 6682**
ph (in N NaF)	-0 3012	-0 4812*	0 5317**	0 4498*	-0 2101	-0 3897*	0 0715
pH (in 0 01 $CaCl_2$)	-0 0314	0 8052**	0 2474	-0 0244	0 6728**	0 6086**	0 5966**
Electrical conductivity	-0 1951	0 7405**	-0 2051	-0 1666	0 6498**	0 7052**	0 6444**
Available Nitrogen	-0 2370	0 1561	0 0005	-0 1247	0 1605	0 3757*	0 3726*
Available phosphorus	0 0133		-0 3139	-0 2531	0 5425**	0 6137**	0 4072*
Calcium	-0 0884	0 8387**	-0 1689	-0 0837	0 6353**	0 5961**	0 6809**
Magnesium	0 1584	0 4231*	0 2048	0 2734	0 5407**	0 4747**	0 5990**
Total copper	0 3659*	0 1723	-0 3948*	-0 3337	-0 0780	-0 0018	-0 1895

r_{27} 05 0 3652

r_{27} 01 0 4678

* Significant at 5 per cent level

** Significant at 1 per cent level

APPENDIX X

Profile mean / average value of important soil properties

Sl No	Soil properties	Deciduous forest	Cashew plantation	Semi-evergreen forest	Eucalyptus plantation	Evergreen forest	Tea plantation	Shola forest	Acacia plantation
1	Gravel (per cent)	43 01	42 79	41 71	46 31	39 93	44 78	33 44	28 47
2	Coarse sand ( )	35 97	35 19	48 67	35 57	54 71	41 78	47 22	50 18
3	Fine sand ( )	8 07	12 49	9 43	9 23	14 02	11 52	11 31	12 04
4	Clay (")	28 85	23 43	21 32	30 83	16 12	27 27	19 43	13 59
5	Fine sand/Coarse sand ratio	0 23	0 35	0 20	0 28	0 26	0 30	0 24	0 25
6	Sand + silt/clay ratio	2 49	3 24	4 27	2 34	5 34	2 61	4 45	6 42
7	Bulk density	1 14	1 16	1 23	1 21	1 19	1 15	1 23	1 19
8	Maximum water holding capacity (per cent)	40 52	35 72	37 57	36 42	33 33	34 14	33 59	34 53
9	Pore space ( )	43 80	41 98	40 47	39 10	39 84	42 32	40 45	43 12
10	Volume expansion ( )	7 89	7 25	5 02	6 31	4 22	4 42	5 78	4 66
11	Aggregate stability ( )	83 04	75 02	72 0	69 08	65 80	57 01	51 91	81 15
12	Mean weight diameter (mm)	3 02	2 60	3 91	3 13	3 09	2 95	2 90	2 92
13	pH (in distilled water)	4 38	4 53	4 50	4 35	4 57	5 60	4 28	4 60
14	Electrical conductivity (m mhos cm ^{1})	0 09	0 09	0 07	0 07	0 05	0 15	0 06	0 05
15	Cation exchange capacity (C mol(p^{+}) kg^{-1}	10 71	12 67	9 56	9 09	5 95	6 65	8 63	7 92
16	Total nitrogen (per cent)	0 168	0 183	0 148	0 165	0 156	0 156	0 130	0 183
17	Available nitrogen($\mu g\ g^{1}$)	91 75	78 33	78 75	94 00	82 67	90 33	95 80	73 00
18	Total phosphorus (per cent)	0 0603	0 1087	0 0701	0 1 29	0 0627	0 0838	0 0962	0 0957
19	Available phosphorus ($\mu g\ g^{1}$)	2 88	2 70	35	1 58	5 13	9 70	0 48	0 13
20	Total potassium (per cent)	0 204	0 266	0 308	0 238	0 174	0 137	0 236	0 291
21	Available potassium ($\mu g\ g^{1}$)	98 50	115 00	65 00	44 50	151 33	110 33	66 20	87 00
22	Calcium ($\mu g\ g^{1}$)	133 50	21 67	155 75	76 75	60 00	635 67	95 00	58 00
23	Magnesium (")	736 75	922 67	1042 25	781 50	822 00	2871 67	1568 20	3279 67
24	Total iron (per cent)	2 772	3 071	2 247	3 314	1 329	2 825	3 095	4 503
25	ater solube iron ($\mu g\ g^{1}$)	6 25	8 00	4 25	4 00	3 00	21 30	1 80	8 00
26	DTPA extracable iron ( )	172 25	199 00	104 75	21 25	60 67	7 67	166 20	207 00
27	Dithionite extractable iron (")	15767	18547	11375	23175	3930	11370	18788	24943
28	Oxalate extractable Iron( )	2722 50	4056 67	2705 00	2795 00	1660 0	2043 33	4224 0	7170 00
29	Active iron ratio	0 1975	0 2367	0 2475	0 1250	0 2833	0 1500	0 2600	0 2767
30	Total aluminium (per cent)	9 322	9 571	9 419	11 698	6 109	8 551	10 118	10 966
31	Total manganese ($\mu g\ g^{1}$)	107 75	93 00	94 75	60 25	143 67	126 67	114 20	487 00
32	Total zinc (")	130 60	149 58	186 0	181 88	132 67	123 52	75 52	100 26
33	Total copper ( )	33 25	54 00	28 75	59 00	105 00	73 00	36 80	37 33

COMPARATIVE MORPHOLOGY AND PHYSICO-CHEMICAL PROPERTIES OF SOME FOREST AND DEFORESTED SOILS OF KERALA

By

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ABSTRACT

In Kerala, continuous denudation of forests along the Western Ghats region has brought about hastening of the process of laterisation which becomes one of the major constraints to agricultural development. Deforestation of different typesof forests such as deciduous, semi-evergreen, evergreen and shola may bring about laterisation to different extents. Deforestation and monoculture with different economically important species and plantation crops may delay or hasten the process of laterisation. The present study is, therefore an attempt to understand more about the effect of different monoculture vegetation such as cashew, eucalyptus, tea and acacia on soil properties in comparision with soils of adjoining virgin soils in deciduous, semi-evergreen, evergreen and shola forest ecosystems respectively.

The present study reveals that deforestation has harmful effect on soil irrespective of the type of forest vegetation. It causes mechanical eluviation with higher migration of finer particles from surface downwards, increases bulk density of surface soil and lowers the aggregate stability of the soil.

Organic carbon is found to be partly leached off and eroded off along with mineral soil. It is also burnt faster due to denudation.

The contents of nitrogen and phosphorus increase while that of calcium and manganese decrease as a result of deforestation. Higher amounts of iron and aluminium are noticed in deforested soil than in virgin soils of the natural forests.

The heavy mineral fraction constitutes from 2.5 to 27.6 per cent of the fine sand fraction. The dominant heavy minerals are the black opaques viz , ilmenite, red opaques such as hematite, limonite and geothite, sillimanite and zircon. The lighter fraction of the minerals is constituted mainly of quartz (22.6 to 97.5 per cent) with smaller amounts of feldspars and micas The heavier fraction of the minerals are found to increase in soil due to deforestation brought about by residual accumulation.

The influence of different monoculture/plantations on deforested soil varies with the type of vegetation. Increased root activity exhibited by tea and acacia at lower layers have strengthened the structural stability and improved the single value constants such as low bulk density, higher porosity and water holding capacity of the subsurface soil under these two plantations compared to soils under other plantations and virgin forests.

The degree of weathering of soil varies with the type of vegetation. Based on the silt/clay ratio the soils studied can be arranged in the following order according to the observable factors on the degree of weathering. eucalyptus > tea > deciduous > semi-evergreen > cashew > shola > evergreen > acacia.

Deforestation and monoculture with cashew, tea and acacia enhance the soil pH while monoculture with eucalyptus lowers the pH of the soil.

Acacia is found to enrich the nitrogen status of the soil at a faster rate by its ability to fix atmospheric nitrogen.

The study also reveals that ferrallitization advances in shola forest even if the level of organic matter in the surface soil is 5.19 per cent while no significant ferrallitization has been observed in acacia plantation having only 4.07 per cent organic matter in the surface soil though, both the soils fall under the same ecosystem The critical role played by different type of vegetation in the manifestation of laterisation is yet to be studied.

The micropedogenesis of kaolinite from gibbsite and silica in solution is clearly noticeable in laterised layers of the profile. Conversion of ferrous to ferric iron is also observable in the thin section study of the soils. All soils are laterised with developing argillic horizons and clay skins.

The studies on soils of monoculture plantation crops such as cashew, eucalyptus, tea and acacia in comparison to virgin forest soils offers enough evidences from the present work to show that planted forests/plantation crops favour laterisation in general in comparison to virgin forests. Among the various types of monoculture, eucalyptus appears to enhance later sation to the greatest extent while cashew and acacia favour laterisation to the least.