TAXONOMY AND FERTILITY CAPABILITY ASSESSMENT OF THE SOILS IN COMMAND AREA OF EDAMALAYAR PROJECT

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "**Taxonomy and fertility capability assessment of the soils in the command area of Edamalayar Project**" 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 of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara,
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CERTIFICATE

Certified that this thesis entitled **"Taxonomy and fertility capability assessment of the soils in the command area of Edamalayar Project"** is a record of research work done independently by **Mr. Krishnakumar, P.G.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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We, the undersigned members of the advisory committee of Mr.Krishnakumar, P.G. a candidate for the degree of Master of Science in Agriculture with major in Soil Science and Agricultural Chemistry, agree that the thesis entitled "Taxonomy and fertility capability assessment of the soils in the command area of Edamalayar Project" may be submitted by Mr.Krishnakumar, P.G., in partial fulfilment of the requirement for the degree.

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INTRODUCTION

The soils of the humid tropics are often described as a great reserve for food crop production. Agronomic studies throughout humid tropics have shown that given the proper management and necessary inputs, these soils can produce high yields. The amount of inputs and management requirements vary considerably from place to place. It is essential that natural soil inventories are carried out for determining the potential productivity and increase the production per unit area with minimum inputs. This factor assumes importance in the present day context of increasing pressure on land and high cost of fertilizer inputs.

The command area of Edamalayar irrigation project comprises of 32058.62 hectares and includes dryland and wet land soils. These soils are formed by alluviation of stream and river water and colluvium from side slopes, and mostly occupy the lower aspects of landscape namely, footslope and valleys. Wide variations in physico-chemical characteristics are observed. The soils include well drained laterite and alluvial soil, but the majority are wet lands with aquic moisture regime. A wide diversity exists in rice soils as described by De Datta (1981). The natural drainage varies from good to poor. The parent material ranges from recent alluvium, colluvium to well weathered residual materials. Soil texture varies heavy caly to sand. Organic matter ranges from less than 1 per cent to more than 50 per cent; salt content from 0 to 1 per cent and pH from less than 3 to more than 10. The upland soils cover mostly laterites and alluvium. Most of these soils are characterised by featureless profiles with reddish and yellowish colour. The physical properties are highly favourable for crop production while chemical characteristics are less satisfactory (Sanchez and Buol, 1975).

A perusal of the literature would show that a considerable amount of work has been carried out in tropical soils occurring over a wide range of climatic conditions and geologic materials. Specific mention may be made of the work of Lissonite (1960), Aubert (1962), Lotse et al. (1974) and Greenland (1981).

In Kerala detailed investigations have been carried out on these two groups of soil identified in the command area namely, well drained uplands and rice soils with aquic moisture regime. The study of Hassan (1977) on ribbon valley laterites and Nair (1977) on rice soils of Wyanad are pertinent and cover mostly physico-chemical and fertility characteristics. In respect of uplan soils, Bastin (1985) and Jacob (1987) have carried out detailed investigation on red and laterite soils of Kerala occurring in different locations.

Though soil surveys of Edamalayar command area have been carried out, the data collected could be put to better use if fertility characteristics especially those relating to surface soils are also incorporated. The development of the command area of irrigation project has been given top priority since the formation of Command Area Development Authority. Various aspects of command area development have been taken up with the ultimate aim of increasing production per unit area. It is in this context that the present investigation assumes importance.

With these objectives in view, the present study was undertaken covering eight major soil series, three in uplands and five in wet lands from widely spaced locations of command area. The study has been taken up with the major emphasis on physico-chemical characteristics and fertility parameters in relation to food production. A systematic study of the following aspects was carried out.

1. Morphological features of soil profile
2. Physico-chemical characteristics
3. Extractable iron fractions in relation to genesis of soils
4. Available nutrient status of surface samples

It is hoped that the present study would form the basis for more site specific investigations on soil fertility-plant-water systems so as to arrive at location specific recommendations. The data generated from such studies could be utilised for better and more productive utilisation of these soils to the best advantage.

Review of Literature

REVIEW OF LITERATURE

Morphological characteristics

Koshy and Varghese (1971) characterised the peaty or kari soils by a deep black colour, heavy texture, poor drainage, extremely high content of organic matter and strong acidity.

Nair (1977) in his studies on the profile samples in rice growing soils of Wyanad found that the value of colour lies between 3 and 8 and the chroma between 0 and 8. A shift in the hue between the dry and moist states is observed in some profiles and this change was between 10 YR and 7.5 YR.

Singh et al. (1989) in their studies on alluvial pedogenic complex of Varanasi district in Uttar Pradesh found variations in soil colour which have been attributed to differential colours of parent material. Grey coloured soils of the area exhibit brown through greyish brown to brownish grey colour.

Venugopal et al. (1989) investigated a submerged low land soil profile from Karnataka for morphological and micromorphological features. The study showed that the acquatic environment influenced the morphological and micromorphological properties of the soil. Three distinct zones in the stratified pedon showed characteristic difference with regard to S-matrix and pedofeatures. The presence of sub-rounded skeletal grains with thick grain cutans at 50-75 cm depth formed a demarking zone.

According to Blume and Schlichting (1985), wet land soils are characterised by hydromorphic features (halomorphic, gypsomorphic, calcimorphic or redoximorphic ones, depending on the volume of catchment area), whose arrangement corresponds to differences in redox or water potentials in space and to their changes in time.

According to Sathyanarayana and Thomas (1961) the colour of laterite soils depended on the content and form of iron hydroxide and oxides which imparted the yellow, pink, brown and red colours to the ground matrix and earthy clay.

Sivarajasingham et al. (1962), observed that concretions were formed by successive deposition of sesquioxide films developed at the near surface horizons while concretions consisting of altered rock debris impregnated by ferruginous solutions occured at greater depth.

Brammer (1962) and Ahn (1970) gave a thorough discussion on the influence of topographic site and drainage conditions on the colour variations of laterite soils. Upland, well-drained soils were frequently reddish to reddish brown or brownish red, occasionally very bright red or purplish red. These red colours denoted the presence of a non-hydrated iron oxide haematite in the soil. In the middle and lower-slope soils, drainage was little poorer than in the upper slope and summit soils. The hydrated iron oxides in these soils were mainly goethite and limonite and their presence was responsible for the change in colour from reddish brown to warm brown or orange brown and then to yellowish brown or even brownish yellow.

Rajamannar et al. (1979) studied the profile samples collected from Pudukottai (350 m above MSL) and Kodaikanal (2237 m above MSL) representing low and high level laterite soils under plantations of Eucalyptus teneticornis and E. globulus respectively. Sandy loam was the predominant texture observed. The soils from Kodaikanal contained much higher amounts of organic carbon (0.44 to 9.74%) than those from Pudukottai (0.10 to 1.14%). The organic matter content decreased with depth.

Venugopal (1980) studied the laterite catena in Kerala and reported a decrease in the chroma from the crest to the valley in the case of Varkala and Poruvazhy toposequences. The surface soil colour of the upper midslope member was predominantly red. In the case of lower slope and valley profiles the colour tended to be greyish with depth in the profiles.

Physical properties

Raychaudhury and Anantharaman (1960) observed that the mechanical composition of acid soils cultivated to paddy varied from clayey with a clay content of 59.6 per cent to loamy sand with a sand content of 75 per cent.

Pillai and Subramoney (1967) studied the morphological, physico-chemical and microbiological properties of typical profiles from the kari areas of Vaikom Taluk. The soils can be texturally classified as clays or clay loams. The irregular distribution of various soil seperates in the profiles suggest their formation by deposition and sedimentation.

Chaudhury and Ghildyal (1969) studied the aggregate stability of the puddled soil during rice growth under the common manurial practice. Aggregates of large size (2 to 5 mm) were broken down to small size aggregates as a result of puddling. With the passage of time and under organic manuring, practiced in rice cultivation, the structure was not only regenerated but further improved.

Kyuma (1985) reported that the wet land soils are quite variable in material nature but always have high clay activity, unlike tropical upland soils, which are dominated by low activity clays. The status of major nutrients in tropical wet land soils is not necessarily good, but it is better than that of upland soils. Among the physical characteristics of wet land soils, immunity to soil erosion hazards is the most important characteristic especially in tropical environment.

Ghosh et al. (1973) found that kari soils from Thottappally, North Parur and Kattampally of Kerala State are clay loam in texture and rich in organic matter. The bulk density and particle density varied from 1.24 to 1.40 and 2.50 to 2.65 g/c.c. respectively.

Santhakumari (1975) found that the absolute specific gravity and apparent density of Karapadom soils of Kuttanad varied from 2.82 to 3.93 and 0.98 to 1.36 respectively.

Nair (1977) in his studies on rice growing soils of Wyanad found that the apparent density of profile samples varied from 1.21 to 1.57. The specific gravity of profile samples showed an increasing trend with depth but some showed a decrease with depth.

Prameela and Nair (1985) in their studies on alluvial soils of Kerala found that more than 70 per cent of the available water was removed at tension of 3 bars. The moisture contents of different tensions were correlated to the contents of organic carbon and textural components. The textural components were apparently the determining factors for moisture retention as indicated by the significant positive correlation with the fine fractions (clay and silt) and significant negative correlation with the coarse fractions (fine sand and coarse sand).

Thulaseedharan and Nair (1984) in their studies on laterite soils of Kerala found that the retention properties were correlated to the contents of organic carbon and textural separates. More than 50 per cent of available water in the 2 mm sieved fraction was depleted when tension reached 3 bars. The water content of sieved fraction showed significant positive relation with clay and silt and negative relation with coarse and fine sand fractions.

Mathew and Nair (1985) observed that the field capacity and wilting coefficient values were 10.45 and 7.2 per cent for red soils in Kerala. Significant positive correlations were obtained between moisture contents at different tensions and the contents of clay and silt while the relation with fine sand was significant and negative.

Dongale et al. (1987) in their studies on physical properties and fertility parameters of lateritic soils in relation to their irrigability classification found that the effective soil depth, gravel content, and texture of surface soils (0-20 cm) ranged between 0.52 and 1.25 m, 11 and 28 per cent and clay loam to clay, respectively. The moisture content at field capacity and permanent wilting point varied between 27.15 and 30.30 and 16.16 and 18.10 per cent, respectively with available water range of 158 to 199 mm/m of soil depth.

Bastin (1985) reported a positive correlation between moisture retention at 1, 2, 5 and 15 bars and clay content in red soils from different regions of Kerala. Highly significant positive correlation was obtained between clay and 15 bar moisture (r = 0.590**).

Chemical properties

Jeffery (1961) stressed the importance of the iron system in flooded soils in preventing low redox potentials and maintaining what he termed 'healthy redoxing conditions'.

Grant (1964) pointed out that paddy soils with well developed iron pans are formed predominantly on well drained, acidic, iron-rich soils with ample controlled irrigation.

Pisharody (1965) reported that the total iron present in the water logged soils varied from 16,000 to 1,32,000 ppm. The amount of total iron in the dry soils is of the same order as that in the water logged soils.

Singh and Ram (1975a) reported that the amount of total iron was found to vary from 1.82 to 3.45 per cent. Higher amounts of iron were found generally in the soils which contained high percentage of clay fractions. The amount of free iron varied from 0.24 to 1.45 per cent. It showed a significant negative correlation with soil pH ($r = 0.637$). Free iron did not show any significant correlation with organic carbon.

Singh and Ram (1975b) found that the total and combined iron increased with depth in both alluvial and red soil profiles. Free iron tended to decrease with depth in alluvial soils. The free iron content varied from 0.1 to 0.88 per cent in alluvial soils.

Nair (1977) in his studies on the profile samples in rice growing soils of Wyanad found that the Fe_2O_3 content tend to increase with depth to a maximum in the lowest layer.

Acharya et al. (1979) in their studies on distribution of iron in paddy soils of Sambalpur found that the total iron ranged from 1.2 to 5.4 per cent, ferrous and ferric content varied from 0.15 to 0.47 per cent and from 0.85 to 4.9 per cent respectively.

Venugopal (1980) found the Fe_2O_3 content of soil profiles of Varkala toposequence to range between 1.16 per cent and 10.92 per cent. The Al_2O_3 content varied from 3.13 to 25.28 per cent.

Bhattacharya et al. (1983) investigating the red soils of Karnataka derived from granite genesis attributed higher values of total Fe_2O_3 at lower depths of soil to pedogenic factors. The total iron content varied from 7.2 to 29.0 per cent.

Nair (1945) observed that the important feature of the kari soils of Kerala was their high content of organic matter. According to him, the organic matter, exchangeable hydrogen, pH and C/N ratio are interrelated and have a direct bearing on their low fertility status.

Koshy (1970) found that the C/N ratio ranged from 12.17 in a submerged rice soil to 23.67 in a kari soil.

Menon (1975) studying the morphological and physico-chemical properties of the kayal soils of Kuttanad in Kerala reported a significant negative correlation between organic carbon and pH.

Nair (1977) in his studies on rice growing soils of Wyanad reported that the organic matter content of surface samples ranges from 0.4 to 3.8 per cent, while in profile samples there is a marked trend to decrease with depth.

Bastin (1985) observed the organic carbon content of red soils of Kerala to range between 0.17 to 0.74 per cent and noted a steady decrease in organic carbon content with depth in the profile.

Raychaudhury and Anantharaman (1960) found that in Indian soils growing paddy, the nitrogen decreased with depth in the profile.

Venugopal (1969) found the nitrogen content of the different types of soils of Kerala varied from 0.01 to 0.54 per cent. The minimum was noted for an alluvial soil and the maximum value for kari soil. The general trend in the distribution was for a decrease in its content with depth.

Varghese (1972) studying the acid soils of Kerala recorded 0.49 to 0.55 per cent nitrogen in kari soils.

Hassan (1977) reported the total nitrogen content of the wet land soils of the ribbon valleys of Kerala to range from 0.075 to

0.2 per cent. In the profiles, a decrease in total nitrogen was observed and this decrease paralleled the organic matter content.

Nair (1977) in his studies on rice growing soils of Wyanad reported that the total nitrogen content varied between 0.02 and 0.17 per cent.

Parvathappa (1964) in his studies on the productivity of red soils of Mysore State indicated that total nitrogen and carbon/nitrogen ratio were medium in surface soils and decreased with depth.

Raguraj (1981) reported a decrease in total N with depth in the case of laterite soil profiles of Madurai.

Koshy and Brito-Mutunayagam (1965) found the level of total P in Kerala soil profile to vary from 0.024 to 0.256 per cent.

Venugopal (1969) in his studies on soils of Kerala reported that kari soils have low P_2O_5 content.

Khan and Mandal (1973) studied the distribution of different forms of soil phosphorus in rice soils of West Bengal. The total phosphorus ranged from 177.1 to 543.7 ppm with a mean value of 311.6 ppm. The organic phosphorus constituted about 34.7 per cent of total amount. Both total and organic phosphorus were found to be significantly correlated with organic matter.

Nair (1977) observed that the total P_2O_5 content ranging between 0.01 and 0.13 per cent in rice growing soils of Wyanad.

Raychaudhury and Reddy (1963) reported that the red soils of Bangalore district having sand to clay loam texture are low in available P_2O_5 ranging between 11.2 and 22.4 kg/ha.

Iyer (1979) reported a total ((P_2O_5) content which ranged from 0.025 to 0.41 per cent in the profiles of red soils at Trivandrum.

Raguraj (1981) observed the available phosphorus content for the red soils profiles of Tamil Nadu to range from 0.04 to 22.4 kg/ha.

Koshy and Brito-Mutunayagam (1965), in their studies on fixation and availability of phosphorus in Kerala soils found that the soil studied differ in their capacity to fix phosphorus. Acid soil with high sesquioxide content have high capacity for fixation. The downward movement of phosphorus in Kuttanad soils was very low.

Kuo and Mikkelson (1979) investigated two, paired soil profiles - flooded rice and irrigated pasture - to elucidate adsorptive changes of phosphorus as a consequence of long term seasonal soil flooding. The adsorption of phosphorus was considerably higher in the flooded rice top soil, 0 to 30 cm depth, then in the upland top soils. The differences in phosphorus adsorption decreased as soil depth increased. High phosphorus adsorption on the rice top soil was attributed to the higher content of amorphous iron resulting from reduction caused by seasonal soil submergence.

Nair and Padmaja (1983) found significant correlations between P fixation and silt, clay, total calcium, total iron and sesquioxides. pH of the soil did not show any relationship to their P fixing capacity.

Nad _et al_. (1975) determined the phosphorus fixing capacity of the different major soil groups of India. Clay and free iron oxide contents of the soils were the two dominant factors determining the phosphorus fixing capacity. Amongst the various soil groups, black, red, laterite, mixed red and black, red and yellow and coastal alluvial soils exhibited higher phosphorus fixation than alluvial, grey brown, desert and other soils. The ranges of phosphorus fixation were 44.0 to 70.2 per cent for black, 12 to 47.0 per cent for alluvial, 21 to 55 per cent for laterite and 28 to 85.2 per cent for red soils.

Kothandaraman and Krishnamoorthy (1978) investigated phosphorus fixing capacity of red, black, alluvial and laterite soils of Tamil Nadu. The phosphorus fixing capacity of soils ranged from 20 to 183 mg P/100 g soil with a mean of 85 mg P/100 g. The soils were found to differ widely in their phosphorus fixing capacity the highest values being for the high level laterites of Ootacammund and the lowest for alluvial soils. The phosphorus fixing capacity was found to be positively correlated with clay, total sesquioxides and total alumina. Red soils recorded a phosphorus fixing capacity of 51 mg P/100 g soil.

Ramanathan and Krishnamoorthy (1973) studied the changes in progressive availability of potassium in three major soil groups of Tamil Nadu under the influence of graded doses of NPK fertilizer at successive growth stages of paddy. The available potassium status readily increased with the time of submergence. This increase was attributed to the increase in the exchangeable K from non-exchangeable form during submergence.

Amma and Aiyer (1973) in their studies of potassium status of rice soils of Kerala found that the kari soils had the highest cation exchange capacity and the content of exchangeable potassium was fairly high.

Ram and Singh (1975) found that available K was positively and significantly correlated with pH, exchangeable Ca^{2+}, $CaCO_3$ and clay content of the soils. Fixed content also gave significant positive correlations with clay content, pH and available K.

Nair (1977) reported that the total K_2O content varying between 0.01 and 0.15 per cent in rice growing soils of Wyanad.

Ge and Su (1986) in their study of Chinese paddy soil samples derived from various river deposits found that the amount of total, slowly available and available K were higher in light clay soils than in medium loam soils.

Halim et al. (1963) investigating the potassium status of the U.A.R. soils found that total potassium varied between 2.5 me/100 g in coarse textured soils to 15 me/100 g in fine textured soils. The total potassium content was highly correlated with the clay percentage and exchangeable potassium.

Nair (1973) found the total K_2O content of red soils of Kerala to vary from 0.92 to 1.44 per cent for the surface samples and from 0.87 to 1.37 per cent for subsurface samples.

Venugopal (1969) reported the percentage of total CaO varied from 0.02 to 2.03 per cent in the different soils of Kerala. The lowest value recorded was for a sandy soil and the highest value for a black soil. The total MgO content of the soil varied from trace quantities to 2.69 per cent. The minimum value was observed in a laterite soil and maximum value in black soil.

Venugopal and Koshy (1976) found that the kari soils are peculiar, in that they are submerged and hence show variation in content and behaviour of exchangeable bases. In the profiles studied calcium constituted the predominant divalent cation and the range of exchangeable calcium observed was 3.6 to 4.5 me/100 g. Magnesium formed the next predominent divalent cation, the range observed was 2.2 to 4.18 me/100 g.

Nair (1977) found that the total CaO and MgO contents to increase with depth in some profiles while in other profiles these two bases showed an initial decrease followed by an increase with depth in rice growing soils of Wyanad.

Hassan (1977) observed that the calcium and magnesium status of laterite soils of Kerala were very poor both in surface and subsurface layers of soil profiles. Total calcium increased with depth while magnesium showed a reverse trend.

Nair (1970) reported that the total Zinc content varied from 31.0 to 158 ppm in Onattukara soils and from 59.0 to 93.0 ppm in Kuttanad soils.

Varghese (1971) found that the total zinc content varied from 15.0 to 92.5 ppm and copper content varied from 25 to 168.75 ppm respectively in the alluvial soils of Kerala.

Aiyer et al. (1975) investigating the available zinc, copper, iron and manganese in the kari, karappadam and kayal soils of Kuttanad region of Kerala revealed that all the three soil types are deficient in available copper (90%), available zinc was deficient in 50 per cent of kayal soils suggest the possibility of iron toxicity to rice in these soils.

More et al. (1981) found that the iron and manganese availability increases many fold due to submergence in the medium black and lateritic soils of Konkan. The peak for iron availability is observed between 5th to 6th week of submergence, where for manganese it is at the 4th week of submergence.

Patel and Dangarwala (1984) found that generally negative correlations existed between available iron, zinc and manganese contents and soil pH, $CaCO_3$, silt and clay contents. However positive correlations were observed with organic matter.

Hazra and Mandal (1988) reported that the submergence increased the DTPA extractable iron and manganese content in all soils, the magnitude of such increase ranged from 6 to 28 per cent and 5 to 53 per cent of their initial contents. The DTPA extractable copper and zinc decreased from their initial amounts due to submergence, the magnitude of which varied from 30.4 to 78.5 per cent and 12.7 to 72.9 per cent of their initial amounts.

Rajagopalan (1969) reported that the total manganese in Kerala soils ranged from 103.8 to 9500 ppm.

Praseedom (1970) reported that the total copper content of the laterite soils of Kerala ranged from 9.0 to 78.0 ppm with a mean value of 34.3 ppm. In the red soil profile the copper content varied from 5 to 34.0 ppm with a mean of 17.3 ppm. An increasing trend in copper content was noted with depth in the profile.

Gupta et al. (1980) in a study of the alluvial profiles of Haryana found the available copper content to be significantly correlated with organic carbon and clay.

Reaves and Berrow (1984) found the copper content to increase with depth in the Scottish soil profiles. Copper content of organic soils was less than that of mineral soils. Copper content was also found to be inversely related to sand content.

pH and cation exchange properties

Pisharody (1965) reported that the pH ranged from 2.9 to 5.4 and cation exchange properties ranged from 2.4 to 24.2 me/100 g soil respectively in rice soils of Kerala.

Dev and Sharma (1971) found that the pH values increased in all soils except those which were calcareous in nature. Increase in pH has been attributed to increased content of reducible manganese and not so much to reducible iron.

Kurup and Aiyer (1973) in their studies in the Kari (peat), Karapadam (river borne alluvium) and Kayal (reclaimed lake bed) soils of Kuttanad were examined for their pH and electrical conductivity for consecutive three years from 1965. All the three types registered the maximum and minimum values for the soil pH and the minimum and maximum values of electrical conductivity when sampled during the period of October-November and March-April respectively.

Sahu and Acharya (1976) found that flooding of soils causes changes in soil reaction and its electrical conductivity. At two days of submergence the pH of each soil decreased and thereafter increased.

The initial decrease was probably due to production of organic acid and accumulation of carbon dioxide and subsequent increase was due to reduction of certain inorganic constituents like iron and zinc in soil.

More et al. (1982) in their studies on the effect of submergence on the electro-chemical and chemical properties of medium black and lateritic soils of Konkan revealed that on submergence the pH of soil stabilised around neutrality (6.7 to 7.0) whereas electrical conductivity doubled. No influence of submergence on exchangeable K_2O content was noticed.

Rao and Narasimham (1986) found that after four months of flooding, the alluvial soils have shown an increase in cation exchange capacity ranging between 1.11 and 22.7 per cent in some soils but a decrease in some soils ranging between 12.7 to 0.40 per cent. Exchangeable calcium, potassium and sodium contents of most soils increased after flooding and only exchangeable magnesium showed a decrease.

Satyanarayana and Thomas (1962) observed the CEC (NH_4OAc) of laterite soil of Angadipuram to vary from 4.5-5.8 me/100 g in the profile. The value for the profile from Kasaragod area was 2.5-7.0 me/100 g.

Venugopal and Koshy (1976) reported that the red soils of Kerala state were poor in exchangeable bases. The occurrence of bases decreased in the order of calcium > magnesium > potassium > sodium. The cation exchange capacity cranged from 1.62 me/100g for a laterite to 49.56 me/100 g for black soil. In the laterite profiles, calcium formed the predominent exchangeable base followed by magnesium.

Raguraj (1981) in a study of the red laterite, alluvial and black soils of Madurai district reported that the pH ranged in the profiles from 6.0 to 10.10 in red soils, from 8.2 to 9.9 in black soils, 8.2 to 9.9 in alluvial soils and 3.4 to 6.3 in laterite soils. The low pH (below 6.0) in the laterite soils was attributed to the high organic matter content and also leaching of bases. The pH of the surface soil was high compared to subsurface layer.

Iron fractions and active iron ratio of soils

Singh and Ram (1979) found that all forms of Fe^{2+} increased with the time. Water soluble and exchangeable Fe^{2+} in the alluvial soils increased progressively with the advancement of time. Active and inactive Fe^{2+} also increased with the submergence period.

Nikolayeva et al. (1987) in their investigation of the forms of iron in paddy soils showed that the active (non silicate) forms account for 30-40 per cent of the total. The amount and relative proportions of the amorphous and crystalline forms of iron indicate that iron is extremely active throughout the profile of flooded soils and in the humus horizon of soils that are only slightly irrigated.

Iyer (1979) in his study of red soils of Kerala found that the dithionite extractable iron content of Varkala profiles ranged from 76.0 to 175 ppm. At pilicode, it ranged from 146.30 to 190.00 ppm and at Patchalloor it ranged from 129.00 to 193.42 ppm. The dithionite extractable iron content increased with depth in all the three profiles.

Schwertmann and Taylor (1977) reported that the solubility of iron in ammonium oxalate solution expressed as the active iron ratio, Fe_o/Fe_d was usually interpreted as indicating the degree of crystallinity of iron oxides in the sample.

Bhattacharya et al. (1983) reported that the citrate-bicarbonate -dithionite extractable iron content in red soils of Karnataka derived from granite gneiss ranged from 0.88 to 34.37 per cent and constituted 20.6 to 73.7 per cent of the total iron content.

Arduino et al. (1984) reported that the relative age of soils can be estimated from the amounts of iron, extracted by dithionite and oxalate. The large the proportion of total iron (Fe_t) extracted by these reagents especially by dithionite (Fe_d), the older the terrace. The proportions of total iron extracted by dithionite over and above those removed by oxalate (Fe_o) offer the best basis for determination of the age. They found the total iron to range between 2.14 to 8.30 per cent and that of Fe_o from 0.04 to 0.84 per cent in the soils of Western Po Valley in Italy.

Bastin (1985) investigating red soils of Kerala found that the Fe_d ranges between 1.24 per cent to 3.56 per cent. The oxalate extractable iron recorded low values compared to Fe_d and it ranges from 0.001 to 0.004 per ent respectively.

Arduino et al. (1986) working on soils of northern Italy observed increase in the Fe_d/Fe_t and Fe_d-Fe_o/Fe_t ratios with age of the terrace.

Jacob (1987) investigating laterite soils from different parent materials in Kerala found that the Fe_d ranged from 0.85 per cent to 10.87 per cent and Fe_o ranged from 0.06 to 0.84 per cent respectively.

Classification

a) Taxonomy

Luzio (1985) found that in the Central part of Chile, most soils with excess wetness are Ochraqualfs and Haplaquolls. Most of the wet soils on volcanic ash are placaquepts. They are rather shallow soils with impeded drainage. The presence of the placic horizon between the ash and the unrelated glacifluvial substraturn is considered the main cause for the impeded drainage of these soils.

Somasiri (1985) noted that the important rice growing soils of tropical regions are wet alfisols. They are mainly located in areas with dry climates. Most of them have an aquic or an anthraquic moisture regime.

In earlier classification system of many countries most oxisols were called latosols. This term was coined to designate all zonal soils having their dominant characteristics with low silica sesquioxide ratio, low base exchange capacity, low activity of clays and low content of weatherable minerals (Kellogg, 1949).

Maignien (1966) and Sye (1968) indicated that the laterite soil could come under either oxisols, alfisols, ultisols or inceptisols of comprehensive system of classification.

Jacob (1987) indicated that the laterite soils from different parts of Kerala come under the order oxisol.

b) Fertility capability classification

Buol and Couto (1981) indicated that one could view the Fcc system as a check-list of soil properties that should be considered in comparing results of field crop trials and in extrapolating these results. Only soil properties relatively near the soil surface are used as criteria in defining each group. It focuses attention on these soil properties most directly related to management of crops in the field and is best used as an interpretive classification in conjuction with a more inclusive natural soil classification system.

Mohanty and Filipovski (1981) characterised rice growing soils in Yugoslavia for their mechanical, physical, electrochemical, chemical and clay mineralogical characters. Fertility potential classification was attempted using factor analysis technique which extracted four independent and uncorrelated factors explaining 75% of the total variability. These factors, in order of importance, were formed as inherent potentiality factor, phosphate factor and potassium supplying factor. Basing on factor scores the individual soils were graded for these factors. The ranking of the soils appeared to be quite satisfactory and were in agreement with soil chemical analysis.

Mohanty and Filipovski (1982) evaluated rice growing soils of different types for their fertility potential considering thirty characters and using principal component analysis. The principal component analysis synthesised five components explaining 77 per cent of total variability. In the case of first component, some of the problematic soils gave good ranks which might have resulted from the undesired soil characters affecting its fertility. Whereas grading with respect to the second, third and fourth components appeared to be more logical. It Is suggested that the undesired characters which gives unnecessary high scores to the problem soils while applying principal component analysis for fertility evaluation should be eliminated.

Materials and Methods

MATERIALS AND METHODS

The investigations carried out in this study relate mainly to eight soil series under Edamalayar Irrigation Project. These soil series were identified by the Soil Survey Unit of the Department of Agriculture, Kerala State. The areas selected for the study are indicated in Fig. 1.

1. Field studies

Profile pits were dug in the typical areas identified and morphological features were observed horizon-wise and recorded as per Soil Survey Manual (1970). The salient features of the areas in respect of location, physiography, drainage, vegetation and land use were also recorded. The morphological description of the soil profiles are presented in Appendix 1.

1.1. Sample collection

After morphological examination of the profiles, soil samples representing the different horizons in a profile were collected for laboratory examination. Surface samples, 0-20 cm were also collected from widely distributed areas in a soil series for estimating the available nutrient status. The particulars of soil samples collected are presented in Table 1.

Fig. 1. LOCATION MAP OF EDAMALAYAR AYACUT

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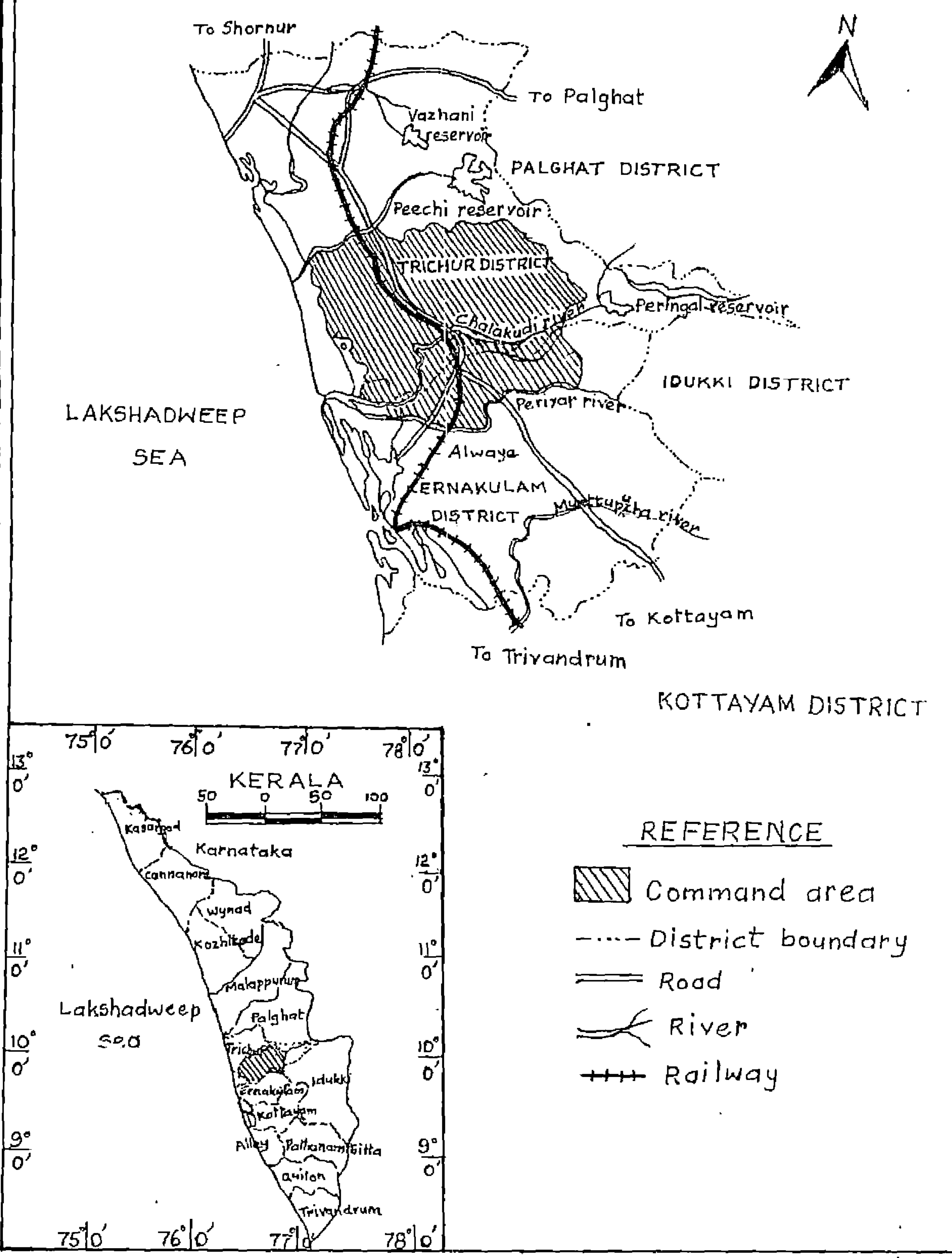

Table 1. Details of profile sample collected

Profile No.	Soil Series	Location	Sample No.	Horizon	Depth (cm)	Area (ha)
1	2	3	4	5	6	7
I	Thodupuzha (uplands)	Kothakulangara (Alwaye)	1	Ap	0-22	7378.83
			2	B_1	22-52	
			3	B_{21}	52-91	
			4	B_{22}	91-119	
			5	B_3	119-180	
II	Mulamthuruthy (paddy lands)	Athany (Alwaye)	6	Ap	0-15	2527.84
			7	A_3	15-42	
			8	B_1	42-60	
			9	B_2	60-94	
			10	B_3	94-150	
III	Kothamangalam (paddy lands)	Angamaly (Alwaye)	11	Ap	0-14	1703.02
			12	A_3	14-34	
			13	B_1	34-67	
			14	B_{21}	67-107	
			15	B_{22}	107-150	
IV	Punnamattom (uplands)	Chovvara (Alwaye)	16	Ap	0-14	2055.54
			17	B_1	14-43	
			18	B_{21}	43-84	
			19	B_{22}	84-122	
			20	B_3	122-200	
V	Ikkanadu (paddy lands)	Cherianadu (Alwaye)	21	Ap	0-19	5152.38
			22	A_1	19-54	
			23	B_1	54-85	
			24	B_{22}	85-150	

Contd.

Table 1. Continued

1	2	3	4	5	6	7
VI	Ayyanthole (paddy lands)	Potta (Mukundapuram)	25	Ap	0-10	1586.17
			26	B_{21}	10-35	
			27	B_{22}	35-70	
			28	B_{23}	70-110	
VII	Konchira (paddy lands)	Thrikkakkara (Kanayanoor)	29	A_1	0-15	1594.08
			30	B_{21}	15-33	
			31	B_{22}	33-57	
			32	B_3	$57\text{-}110^+$	
VIII	Velappaya (uplands)	Pariyaram (Mukundapuram)	33	Ap	0-18	1505.38
			34	B_1	18-43	
			35	B_{22}	43-85	
			36	B_{23}	85-122	
			37	B_3	$122\text{-}150^+$	

2. Laboratory studies

2.1. Preparation of samples

The soil samples collected were air dried, ground with a wooden mallet and passed through a 2 mm sieve. The sieved samples were utilized for the study of various physico-chemical properties.

2.2. Physical properties

The particle size distribution was carried out by the International Pipette Method (Piper, 1942).

Moisture retention studies were conducted in a pressure plate apparatus using ceramic plates (Richards, 1954). Physical constants were determined using Keen Raczkowski boxed by the method outlined by Sankaram (1966).

3. Chemical properties

The chemical properties of samples were determined by standard analytical procedure and expressed on moisture free basis.

3.1. Analysis of profile samples

Soil reaction was determined in a 1:2.5 soil water suspension using a Systrionics pH meter and electrical conductivity in a 1:2.0 soil water suspension using an Elico conductivity meter. Organic carbon was determined by Walkley and Black method and total nitrogen was determined by semi micro-kjeldahl method (Soil Survey Staff, 1967).

Total Fe_2O_3, F_2O_5, K_2O, CaO, MgO and Na_2O were determined in the perchloric-nitric acid (1:2) extracts (Hesse, 1971). Total iron was determined by o-phenanthroline method while total CaO and MgO were determined by IL 257 atomic absorption spectrophotometer. Total P_2O_5 content was estimated by vanadophosphoric yellow colour method (Jackson, 1958) and total potassium and sodium by flame photometry using an EEL flame photometer.

Cation exchange capacity was determined by the NH_4OAc method and exchange acidity was determined in the 1N KCl extracts (Soil Survey Staff, 1967). Exchangeable calcium and magnesium in the neutral 1N NH_4OAc extract were determined by EDTA titration method as outlined by Hesse (1971). Exchangeable potassium and sodium were read using EEL flame photometer (Jackson, 1958).

Free iron oxide was extracted using dithionite-citrate-bicarbonate method (Mehra and Jackson, 1960) and determined colorimetrically by the o-phenanthroline method. Amorphous iron oxide was extracted in the dark using ammonium oxalate (Mc Keague and Day, 1966) and determined by o-phenanthroline method (Hesse, 1971).

3.2. Analysis of surface samples

Available nitrogen was determined by the alkaline permanganate method (Subbiah and Asija, 1956). Available P_2O_5 was extracted using Bray 1 extractant (0.03 N NH_4F in 0.025 N HCl) and determined by molybdophosphoric acid method. Available potassium and sodium were extracted using neutral 1N NH_4OAc and determined using a flame photometer (Jackson, 1958). Phosphorus fixing capacity was determined by the method described by the Hesse (1971).

Results

RESULTS

1. Environmental factors affecting the study area

1.1. Climate

Climate of the area is humid tropical with hot summers. Annual rainfall averages 3000 mm and the temperature ranges from 19 to 35.25°C. The two monsoons North East and South West are common to the area as in other parts of the State. The South West monsoon which sets in June, accounts for the major portion of precipitation received. Summer months are characterised by high day temperature and scanty rains.

The relative humidity remains very high through out the year and it goes upto 96.06%. High velocity winds in August-September occasionally cause crop damage.

1.2. Geology

The main rock types found are charnockite gneiss and basic dykes. Sub-recent laterites are seen extensively in the area followed by recent sediments in the western region. Laterite is buff coloured which is developed in the sub-mountainous and flat topped ridges and hills. Laterite are seen as a capping over all types of rocks. Alluvium is noticed all along the streams and river channels. Beach sands are noticed in the western portion of the command area.

The charnockites are coarse grained granulite rocks and are generally dark coloured. The foliation is not very well marked and the rock is massive. The gneisses include rocks, showing well defined foliation, like garnet-sillimanite etc.

1.3. Natural vegetation

The trees, shrubs and herbs that are characteristics of humid tropical zone are found in this area also. Different varieties of trees, shrubs and herbs are seen flourishing well here. Some of the important trees are Artocarpus integrifolia (jack), Mangifera indica (mango), Nichossia elliphic (pala), Erythrina indica (murukku), Anacardium oxidentale (cashew), Tamarindus indica (Tamarind), Ficus bengalensis (Alu), Bombax malabaricum (Elavu), Strynes nuxvomica (Kanjiram) etc.

Important among the dry weeds are Cynadon dactylon (Karuka pullu), Panicum sp., Mimosa pudica (Thottavady), Almenda cathartica, Eupatorium odoratum (Communist pacha), Euphorbia hirta (Euphorbea), Lantana camara (Lantana), Colocasia etc.

Important wet land weeds include Cyprus sp. (Muthanga), Panicum sp. (Panicum) and Pistia.

1.4. Present land use

Agriculture is the main occupation of the region. About 60% of the inhabitants depend on agriculture for their livelihood. Holdings are fragmented and the size of holdings ranges from 0.01 hectares to two hectares. Paddy is the most extensively raised crop on low lands followed by coconut in garden lands. Other crops in dry land include arecanut, pepper, banana etc. Intercropping with cocoa, nutmeg, clove etc. is being popularised in the coconut gardens, the major limitations being want of adequate moisture supply.

Due to erratic climatic conditions and lack of adequate irrigation facilities, only one crop (Virippu) is being regularly attempted in most of the paddy lands. The second crop (Mundakan) is raised in area where irrigation is assured. The thrid crop (Puncha) is raised only in a limited area. A portion of paddy fields in Kattoor, Karalam, Edathirinji, Manavalssery, Padiyoor, Poomangalam and Vallivattom, villages comes under upper Kole lands.

2. Profile morphology

Soil series selected for the study from Edamalayar command area include three soils located in uplands consisting of well drained soils covering Thodupuzha, Punnamattom and Velappaya series. The remaining five soil series represent the major area of imperfectly drained paddy lands occupying the valley between the surrounding undulating terrain. The morphological descriptions of the profiles are given in Appendix-I

2.1. Colour

The upland soils mainly Thodupuzha, Punnamattom and Velappaya had surface colour ranging from yellowish brown to dark brown with predominant hue of 7.5 YR. In all these soils the colour hue of sub-surface horizons was 5 YR with not much variation in value and chroma. In the lower layers, colour varied from yellowish brown to yellowish red.

The soil series located in valleys had surface colour ranging from yellowish brown to dark brown with dominant hue of 10 YR, value varying from 3 to 5 and chroma 2 to 4. The sub-surface layers have predominantly greyish colour. The last layer of Mulamthuruthy, Kothamangalam and Ayyanthole showed the presence of red, yellow and brownish mottles.

2.2. Structure

Profiles I, IV and VIII representing uplands had weak to medium sub-angular blocky structure which graded to medium to moderate sub-angular blocky in the sub-surface layer. The structural development was more pronounced in the lower horizons of all these soils. In the case of imperfectly drained paddy soils representing profiles II, III, V, VI and VII weak to moderate sub-angular blocky structure was observed in the surface layer, with massive structure in the lower horizons. The structural development was weak in the lower horizons of profile.

2.3. Coarse fragments

Thodupuzha and Velappaya series had very high gravel content ranging from 35.72 to 72% and 28.1 to 50.2%. In Thodupuzha series, it was maximum in the surface layers, while in Velappaya maximum content was noted in the last but one layer. In Punnamattom series; all the layers had low gravel ranging from 10 to 14%.

In respect of imperfectly drained paddy soils Mulamthuruthy, Kothamangalam, Ayyanthole and Kochira had fairly high gravel content. The range observed was 8.4 to 55.6%, 25.9 to 38.9%, 10.9 to 44.4% and 33.9 to 35.7% respectively. Ikkanadu series had a low content of gravel varying from 12.1 to 17.6%.

2.4. Texture

Thodupuzha, Punnamattom and Vellappaya represented the well drained uplands. The texture ranged from silty loam to silty clay loam. The clay content did not reveal any definite pattern of distribution with depth. In Thodupuzha and Velappaya series, a defenite increase was observed, while in Punnamattom the surface layer showed high clay content as compared to sub-surface layers.

Among the paddy soils, defenite increase of clay in lower layers was observed in Ikkanadu and Ayyanthole. The highest clay content was observed in Konchira series and it varied from 25 to 44%.

Silt was the lowest among the size fractions, but silty texture was predominant varying from silty loam to silty clay loam. The horizon differentiation was more distinct in the well drained profiles I, IV and VIII. Horizon development was feeble in paddy soils.

2.5. Drainage

The internal and external drainage of soils varied widely. Profiles I, IV and VIII were well drained externally and had rapid to moderately rapid permeability. The high gravel content of soils also had a deminant role in deciding permeability of soils. The paddy soils because of their physiographic position being located in valleys were mostly imperfectly drained. The presence of greyish coloured lower layer with mottlings are indicative of impeded drainage conditions.

3. Physical properties

The particle size distribution of soils, mean and range values for profiles are presented in Table 2 and 3. The depthwise distribution of the particle size fraction in the soil profiles is illustrated in Fig. 2.

3.1. *Particle size distribution*

The dry land soils represented by profiles I, IV and VIII are dominated by the sand fraction. It varied from 12.0% for Punnamattam series (No.16) to 57.8% for Thodupuzha series (No.2).

Fig.2. Distribution of particle size fractions in soil profiles

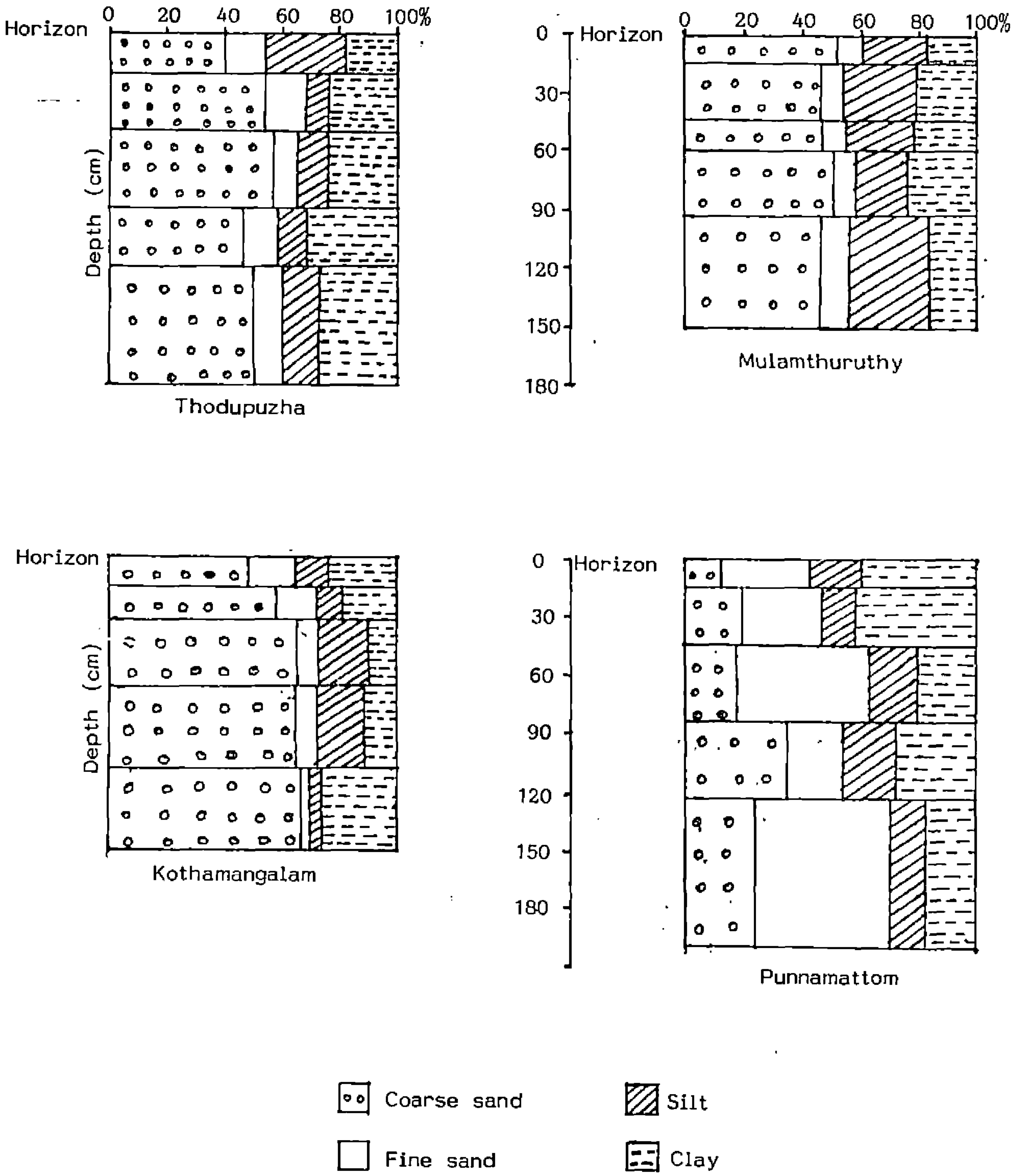

Fig.2. Continued

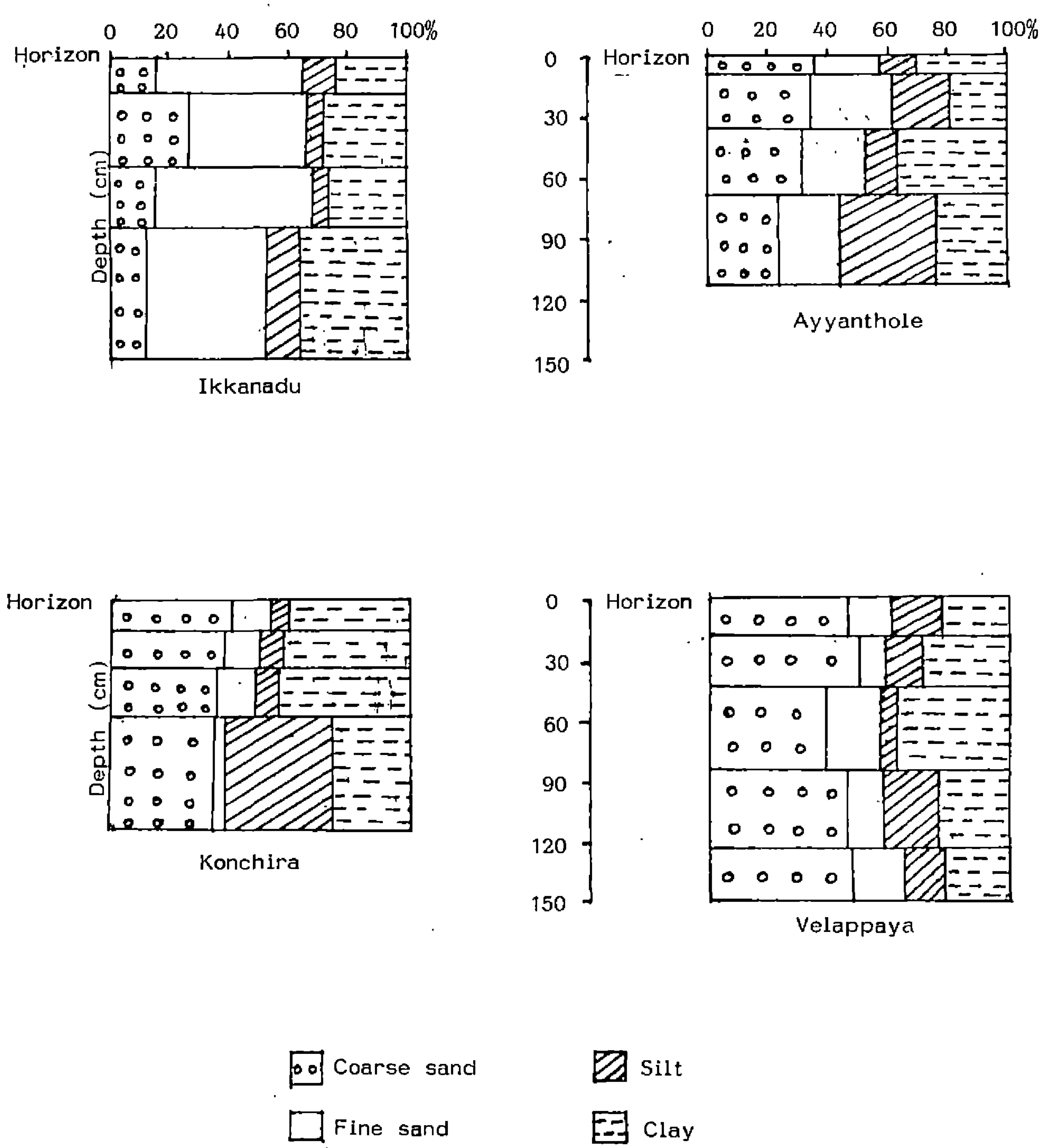

Table 2. The particle size distribution of soils

Soil Series and depth (cm)		Coarse fragments (> 2 mm) (%)	Size class and particle diameter (mm) %				Textural class	Coare sand / Fine sand	Silt/Clay
			Coare sand 2-0.2	Fine sand 0.2-0.02	Silt 0.02-0.002	Clay <0.002			
1		2	3	4	5	6	7	8	9
Thodupuzha									
1	0-22	72.12	40.73	14.15	27.52	17.50	Silt	2.87	1.54
2	22-52	45.16	54.00	14.50	8.00	23.50	Silty loam	3.85	0.34
3	52-91	41.50	57.76	9.2	10.54	22.50	Silty loam	6.20	0.45
4	91-119	35.72	46.60	12.5	10.30	30.60	Silty clay loam	3.68	0.34
5	119-180	44.71	50.00	10.4	13.60	26.00	Silty clay loam	4.80	0.52
Mulamthuruthy									
6	0-15	55.60	52.68	9.36	21.96	16.00	Silty loam	5.62	1.37
7	15-42	36.70	46.60	7.35	25.00	21.05	Silty loam	6.34	1.18
8	42-60	24.30	47.50	8.50	23.00	21.00	Silty loam	5.61	1.12
9	60-94	12.50	51.10	8.70	18.00	22.20	Silty loam	5.87	0.81
10	91-150	8.41	47.16	10.00	27.00	15.84	Silty loam	4.71	1.70
Kothamangalam									
11	0-14	25.92	48.00	16.8	11.5	23.7	Silty loam	2.85	0.48
12	14-34	33.33	58.00	14.00	9.00	19.00	Silty loam	4.14	0.50
13	34-67	35.84	67.00	6.5	16.50	10.00	Silty loam	10.30	1.65
14	67-107	34.21	65.00	8.62	14.38	12.00	Silty loam	7.54	1.19
15	107-150	38.88	66.70	4.80	3.00	25.50	Silty loam	13.89	0.12

Contd.

Table 2. Continued

1		2	3	4	5	6	7	8	9
Punnamattom									
16	0-14	14.00	12.00	31.00	17.00	40.00	Silty clay	0.38	0.42
17	14-43	10.00	18.60	28.40	12.00	41.00	Silty clay	0.66	0.29
18	43-84	12.00	17.30	46.16	16.00	20.54	Silty loam	0.37	0.77
19	84-122	12.50	33.80	20.70	18.00	27.50	Silty loam	1.63	0.65
20	122-200	14.00	23.70	46.30	12.50	17.50	Silty loam	0.51	0.71
Ikkanadu									
21	0-19	17.64	15.60	49.90	11.50	23.00	Silty loam	0.31	0.50
22	19-54	13.33	26.00	41.66	6.00	26.34	Silty loam	0.62	0.23
23	54-85	12.12	15.70	51.80	6.00	26.50	Silty loam	0.30	0.22
24	85-150	16.66	12.90	38.00	12.50	36.60	Silty clay loam	0.34	0.34
Ayyanthole									
25	0-10	10.86	37.68	22.15	10.50	29.67	Silty clay loam	1.77	0.36
26	10-35	31.34	36.40	27.10	18.00	18.50	Silty loam	1.34	0.97
27	35-70	39.16	31.40	21.80	11.00	35.50	Silty clay loam	1.45	0.31
28	70-110	44.44	23.80	20.15	33.00	23.50	Silt	1.18	1.43
Konchira									
29	0-15	35.20	40.00	13.00	6.00	41.00	Silty clay	3.03	0.14
30	15-33	37.70	38.27	11.73	7.00	43.00	Silty clay	3.24	0.16
31	33-57	33.87	35.00	13.00	8.00	44.00	Silty clay	2.69	0.18
32	57-110+	35.61	34.80	4.20	36.00	25.00	Silt	8.20	1.44
Velappaya									
33	0-18	35.37	46.70	13.50	17.00	22.80	Silty loam	3.45	0.74
34	18-43		49.60	8.50	12.90	29.00	Silty loam	5.83	0.41
35	43-85		39.50	18.60	7.00	34.90	Silty clay loam	2.12	0.20
36	85-122		45.85	12.40	18.00	23.75	Silty loam	3.65	0.76
37	122-150+	28.12	47.00	16.40	13.00	23.60	Silty loam	2.86	0.56

Table 3. Particle size distribution (mean and range values for profiles)

Series name	Constituents (%)						
	Coarse fragments (> 2 mm)	Coarse sand (2.0-0.2 mm)	Fine sand (0.2-0.02mm)	Silt (0.02-0.002mm)	Clay (< 0.002mm)	Coarse sand/ fine sand	Silt/clay
Thodupuzha	35.72-72.12 (47.84)	40.73-57.76 (49.81)	9.2 -14.50 (12.15)	8.00-27.62 (14.02)	17.5 -30.60 (24.02)	2.87-6.20 (4.28)	0.34-1.54 (0.64)
Mulamthuruthy	8.41-55.60 (27.50)	46.60-52.68 (49.04)	7.35-10.00 (8.78)	18.00-27.00 (22.9)	15.84-22.20 (19.21)	4.71-6.34 (5.63)	0.78-1.67 (1.21)
Kothamangalam	25.92-38.88 (33.63)	48.00-67.00 (60.94)	4.8 -16.80 (10.02)	3.00-16.50 (10.84)	10.00-25.50 (18.04)	2.85-13.89 (7.78)	0.12-1.65 (4.05)
Punnamattom	10.00-14.00 (12.5)	12.00-33.8 (21.08)	20.7 -46.16 (34.57)	12.00-18.00 (15.10)	17.50-41.00 (29.30)	0.37-1.57 (0.70)	0.29-0.74 (0.55)
Ikkanadu	12.12-17.64 (14.93)	12.9 -26.0 (19.8)	38.00-51.80 (45.34)	6.00-12.50 (9.00)	23.0 -36.60 (28.11)	0.30-0.62 (0.39)	0.21-0.46 (0.31)
Ayyanthole	10.86-44.44 (31.45)	23.80-37.68 (32.32)	20.15-27.1 (22.85)	10.5 -33.00 (18.12)	18.50-35.50 (26.79)	1.18-1.77 (2.46)	0.31-1.50 (0.78)
Kochira	33.87-37.70 (35.60)	34.80-40.00 (37.00)	4.20-13.00 (10.47)	6.00-36.00 (14.25)	25.00-44.00 (38.25)	2.69-8.30 (4.31)	0.14-1.44 (0.48)
Velappaya	28.12-50.15 (37.02)	39.50-49.60 (45.73)	8.50-18.60 (13.88)	7.0 -18.00 (13.20)	22.80-34.9 (26.80)	2.08-5.80 (3.56)	0.20-0.76 (0.52)

For wet land soils also, coarse sand fraction formed the predominant fraction ranging from 12.90 per cent in Ikkanadu series (No.24) to 67.00 per cent in Kothamangalam series (No.13).

The fine sand formed the highest fraction of 46.16 per cent in Punnamattom series (No.18) while the lowest of 8.50 per cent was recorded in Velappaya series (No.34) for dry lands.

For wet land soils, the fine sand fraction ranged from 4.20 per cent in Konchira series (No.32) to 51.80 per cent in Ikkanadu series (No.22). In the Ayyanthole and Konchira series the coarse sand fraction showed a decreasing trend with depth.

Silt was the lowest among the size fractions and it's content varied from 7.00 per cent in Velappaya series (No.35) to 27.62 per cent in Thodupuzha series (No.1) for dry land soils and for wet land soils, it varied from 3.00 per cent in Kothamangalam series (No.15) to 36.00 per cent in Konchira series (No.32). The silt fraction had a dominating influence in the textural class in the soils selected for study.

The clay content varied from 17.50 per cent in Thodupuzha and Punnamattom series (No.1 and 20) to 41.00 per cent in Punnamattom series (No.17), for dry land soil but for the wet land soil series, it varied from 10.00 per cent in Kothamangalam series (No.13) to 44.00 per cent in Konchira series (No.31). The content of clay showed an increasing trend with depth in the Konchira series.

Downward translocation of clay was noticed in all the soil profiles except the Punnamattom series where the second layer showed the highest clay content.

The coarse sand/fine sand ratio varied from 0.37 in Punnamattom series (No.18) to 6.20 in Thodupuzha series (No.3) in the case of dry lands but in the case of wet lands, it ranged from 0.30 in Ikkanadu series (No.23) to 13.89 in Kothamangalam series (No.15).

The silt/clay ratio of the dry lands ranged from 0.20 in the case of Velappaya series (No.35) to 1.54 in the case of Thodupuzha series (No.1) and for the wet lands, it was from 0.12 in Kothamangalam series (No.15) to 1.65 in Mulamthuruthy series (No.10).

3.2. Moisture retention characteristics

The moisture retention characteristics, the mean and range values are presented in Table 4 and 6 respectively.

The amount of water held at 0.3 bar often taken as field capacity, varied from 13.31 per cent in Thodupuzha series (No.3) to 31.20 per cent in Punnamattom series (No.18) for dry lands, in the case of wet lands, it ranged from 6.78 per cent in Mulamthuruthy series (No.7) to 34.00 per cent in Konchira series (No.32). An increase in moisture held at field capacity with depth was observed in the case of Ayyanthole and Konchira series.

Table 4. Moisture retention characteristics of soils (per cent by weight)

Soil series and depth (cm)		Soil moisture tension (bars) 0.3	15	Available water 0.3-15 bar	Ratio of 15 bar moisture to clay
1		2	3	4	5
Thodupuzha					
1	0-22	15.88	8.26	7.62	0.47
2	22-52	16.00	10.02	5.98	0.42
3	52-91	13.31	7.92	5.39	0.35
4	91-119	19.00	13.20	5.80	0.44
5	119-180	17.96	10.07	7.89	0.38
Mulamthuruthy					
6	0-15	9.20	6.50	2.70	0.40
7	15-43	6.78	3.34	3.44	0.16
8	43-60	15.60	8.33	7.27	0.39
9	60-94	16.70	9.50	7.20	0.41
10	94-150	17.20	10.40	6.80	0.67
Kothamangalam					
11	0-14	23.82	7.37	16.45	0.31
12	14-34	13.56	4.65	8.91	0.25
13	34-67	7.66	3.60	4.06	0.36
14	67-107	10.64	7.23	3.41	0.60
15	107-150	8.59	4.04	4.55	0.16
Punnamattom					
16	0-14	30.46	17.12	13.34	0.43
17	14-43	31.30	18.47	12.63	0.45
18	43-84	31.20	14.45	16.75	0.67
19	84-122	30.11	8.32	21.78	0.30
20	122-200	29.00	12.00	17.00	0.66

Contd.

Table 4. Continued

1		2	3	4	5
Ikkanadu					
21	0-19	28.92	10.82	18.10	0.44
22	19-54	27.00	10.50	16.50	0.40
23	54-85	24.90	8.83	16.07	0.31
24	85-150	28.54	13.15	15.39	0.36
Ayyanthole					
25	0-10	10.00	2.30	7.70	0.08
26	10-35	12.00	4.50	7.50	0.24
27	35-70	17.00	9.00	8.00	0.25
28	70-110	20.50	11.40	9.10	0.52
Konchira					
29	0-15	18.20	11.00	7.20	0.27
30	15-33	22.20	13.60	8.60	0.31
31	33-57	24.00	13.60	10.40	0.31
32	57-110	34.00	17.70	16.30	0.71
Velppaya					
33	0-18	19.00	8.70	10.30	0.38
34	18-43	18.60	8.50	10.10	0.30
35	43-85	22.70	13.20	9.50	0.38
36	85-122	23.00	12.50	9.50	0.40
37	122-150	23.20	13.40	9.80	0.42

The moisture held at 15 bar, designated as wilting point ranged from 7.92 per cent in Thodupuzha series (No.3) to 18.47 per cent in Punnamattom series (No.17) for the dry land soils. In the case of the soils from the wet lands, it ranged from 2.3 per cent in the case of Ayyanthole series (No.25) to 17.17 per cent in the case of Konchira series (No.32). An increase in moisture held at 15 bar with depth was observed in the Ayyanthole and Konchira series.

The difference between water held at 0.3 bar and 15 bar, termed as the available water content, varied from 5.39 per cent for Thodupuzha series (No.3) to 21.78 per cent in Punnamattom series (No.19). The available water content showed an increase with depth in the case of Konchira series.

Ratio of 15 bar moisture to clay varied from 0.30 in Punnamattom and Velappaya series (No.19 and 34) to 0.67 in Punnamattom series (No.18) for dry lands. In the case of wet lands, it ranged from 0.08 in Ayyanthole series (No.25) to 0.71 in Konchira series (No.32). The ratio was found to increase with depth in the case of Ayyanthole and Konchira series.

3.3. Physical constants

Physical constants of soils are presented in Table 5 and mean and range values in Table 6.

Table 5. Physical constants of soils

Soil series and depth (cm)		Apparent density g/m^3	Absolute specific gravity	Maximum water holding capacity (%)	Pore space (%)	Volume expansion (%)
1		2	3	4	5	6
Thodupuzha						
1	0-22	1.39	2.28	31.41	43.3	5.7
2	22-52	1.58	2.62	27.16	42.0	2.2
3	52-91	1.32	2.30	34.00	44.0	3.9
4	91-119	1.28	2.40	37.80	49.8	3.9
5	119-180	1.26	2.38	39.00	49.2	4.8
Mulamthuruthy						
6	0-15	1.40	2.39	32.74	45.0	4.7
7	15-42	1.41	2.30	29.00	40.6	2.2
8	42-60	1.35	2.16	30.27	40.2	3.2
9	60-94	1.38	2.08	31.65	63.5	3.1
10	94-150	1.35	2.30	35.00	46.3	5.4
Kothamangalam						
11	0-14	1.26	2.20	53.97	45.6	2.6
12	14-34	1.43	2.56	33.78	47.6	4.6
13	34-67	1.40	2.27	28.0	40.0	1.7
14	67-107	1.53	2.61	30.57	45.0	5.2
15	107-150	1.46	2.08	28.40	32.7	4.2
Punnamattom						
16	0-14	1.04	2.48	59.76	62.0	6.5
17	14-43	1.06	2.57	60.71	63.0	8.7
18	43-84	0.99	2.32	65.33	61.0	12.4
19	84-122	1.08	2.27	54.63	55.4	7.8
20	122-200	1.15	2.59	58.48	61.7	12.9
Ikkanadu						
21	0-19	1.16	2.13	51.64	53.6	15.6
22	19-54	1.18	2.38	50.63	55.0	10.0
23	54-85	1.19	2.31	48.60	54.5	11.3
24	85-150	1.21	2.52	49.40	57.0	9.7

Contd.

Table 5. Continued

1		2	3	4	5	6
Ayyanthole						
25	0-10	1.62	2.50	24.50	38.7	5.2
26	10-35	1.65	2.64	23.50	40.3	3.8
27	35-70	1.50	2.50	29.40	48.0	9.5
28	70-110	1.40	1.91	30.70	49.4	10.1
Konchira						
29	0-15	1.23	2.21	40.00	48.6	6.8
30	15-33	1.33	2.38	37.80	57.1	8.1
31	33-57	1.19	2.14	41.20	49.0	6.7
32	57-110+	0.96	1.96	57.60	57.3	7.7
Velappaya						
33	0-18	1.31	2.30	35.00	49.0	4.5
34	18-43	1.35	2.49	35.00	57.0	4.1
35	43-85	1.24	2.34	37.00	49.4	6.4
36	85-122	1.28	2.50	47.40	59.0	5.2
37	122-150+	1.54	2.10	18.70	26.4	9.3

Table 6. Physical constants, moisture retention characteristics of soils, mean and range values for profiles

Series name	Apparent density (g/cm^3)	Absolute sp. gravity (g/cm^3)	Maximum water holding capacity %	Percentage of pore space %	Volume expansion %	Soil moisture tension (bars) 0.3	15	Available water %	Ratio of 15 bar moisture to clay
1	2	3	4	5	6	7	8	9	10
Thodupuzha	1.26-1.58 (1.36)	2.28-2.62 (2.39)	31.41-39.00 (33.80)	42.0 -49.80 (45.66)	2.2-5.7 (4.1)	13.31-19.00 (16.43)	7.92-13.20 (9.89)	5.39-7.89 (6.53)	0.35-0.47 (0.41)
Mulamthuruthy	1.35-1.41 (1.37)	2.16-2.39 (2.24)	29.00-35.00 (31.73)	40.16-63.50 (47.12)	2.2-5.4 (3.72)	6.78-17.2 (13.09)	3.34-10.40 (7.61)	2.70-7.27 (5.48)	0.16-0.67 (0.40)
Kothamangalam	1.26-1.53 (1.41)	2.08-2.61 (2.34)	28.0 -53.97 (34.93)	32.70-47.6 (42.16)	1.7-5.2 (3.66)	7.66-23.82 (12.85)	3.60-7.37 (5.37)	3.41-16.45 (7.47)	0.25-0.60 (0.33)
Punnamattom	0.99-1.15 (1.06)	2.27-2.59 (2.44)	54.63-65.33 (59.78)	55.40-63.00 (60.61)	6.5-12.9 (9.65)	29.00-31.20 (30.37)	8.32-18.47 (14.07)	12.63-21.78 (16.3)	0.30-0.67 (0.50)
Ikkanad	1.16-1.21 (1.18)	2.13-2.52 (2.33)	48.60-51.64 (50.06)	53.60-57.00 (55.02)	9.72-15.6 (11.65)	24.90-28.92 (27.34)	8.83-13.15 (10.82)	15.39-18.10 (16.57)	0.31-0.44 (0.37)
Ayyanthole	1.40-1.65 (1.57)	1.91-2.64 (2.38)	25.5 -30.70 (27.02)	38.7 -49.4 (44.1)	3.8-10.11 (7.15)	10.00-20.50 (14.87)	2.3 -11.4 (6.8)	7.5-9.10 (8.07)	0.08-0.52 (0.27)
Konchira	0.96-1.33 (1.17)	1.96-2.38 (2.17)	37.8-57.6 (44.15)	48.6-57.3 (53.0)	6.7-8.1 (7.32)	18.2 -34.00 (24.6)	11.00-17.7 (13.82)	7.20-16.3 (10.62)	0.27-0.71 (0.40)
Velappaya	1.24-1.54 (1.34)	2.10-2.50 (2.34)	18.70-47.4 (34.62)	26.40-59.00 (48.16)	4.1-9.3 (5.9)	18.6 -23.2 (21.3)	8.5-13.5 (11.46)	9.5-10.30 (9.84)	0.30-0.42 (0.37)

The apparent density varied from 0.99 g/cm^3 in Punnamattom series (No.18) to 1.58 g/cm^3 in Thodupuzha series (No.2) for dry lands but for the soils from wet lands, it varied from 0.96 g/cm^3 in Konchira series (No.32) to 1.65 g/cm^3 in Ayyanthole series (No.26). An increase in apparent density with depth was observed in Ikkanadu series only.

The abolute specific gravity varied from 2.10 in Velappaya series (No.37) to 2.62 again in Thodupuzha series (No.2) for the dry lands but in case of the soils of the wet lands, it varied from 1.91 for Ayyanthole series (No.28) to 2.64 again in the same series (No.26).

Maximum water holding capacity varied from 18.70 per cent in Velappaya series (No.37) to 65.33 per cent in Punnamattom series (No.18) for dry lands and for the soils of the wet lands, it varied from 23.5 per cent in Ayyanthole series (No.26) to 57.76 per cent in Konchira series (No.32).

Percentage of pore space varied from 26.40 in Velappaya series (No.37) to 63.00 in Punnamattom series (No.17) in respect of dry lands but for the wet lands the lowest value of 32.7 and the highest of 63.5 was noted in Kothamangalam series (No.15) and Mulamthuruthy series (No.9) respectively. The value showed an increasing trend with depth in the case of Ayyanthole series only.

The percentage volume expansion ranged from 2.2 in Thodupuzha series (No.2) to 12.9 in Punnamattom series (No.20) for dry lands. In the case of the wet lands soils, it ranged from 1.7 in Kothamangalam series (No.13) to 15.6 in Ikkanadu series (No.21).

4. Chemical characteristics

4.1. Soil reaction, electrical conductivity and organic constituents of soils

The organic constituents, pH and electrical conductivity and mean and range values for profiles are given in Table 7 and 8 respectively. The depth wise distribution of organic carbon in the soil profiles are illustrated in Fig. 3.

Soils were in general acidic with pH (1 : 2.5 soil water) varying from 4.70 in Thodupuzha series (No.4) to 6.00 again in the same series (No.1) for dry lands but for wet lands, it varied from 3.00 in Konchira series (No.32) to 7.00 in Ayyanthole series (No.28). The pH showed an increasing trend with depth in Mulamthuruthy and Ayyanthole series, while it showed a decreasing trend with depth in Konchira series.

The electrical conductivity of soils ranged from 0.012 mmhos/cm in Velappaya series (No.33) for dry lands but for wet lands, it varied from 0.011 mmhos/cm in Kothamangalam series (No.11 and 15) to 0.350 mmhos/cm in Konchira series.

Fig.3. Distribution of clay and organic carbon in soil profiles

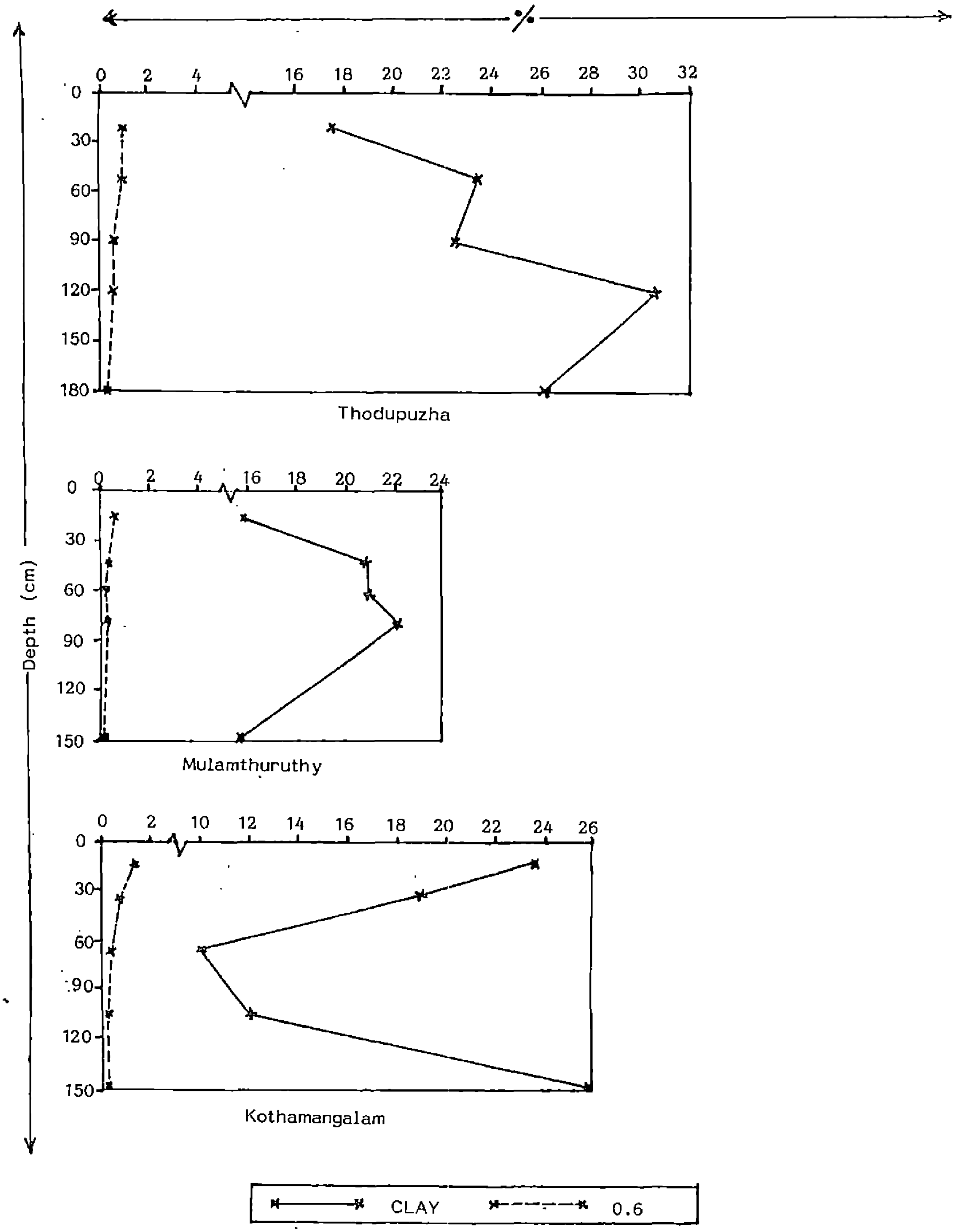

Fig.3. Continued

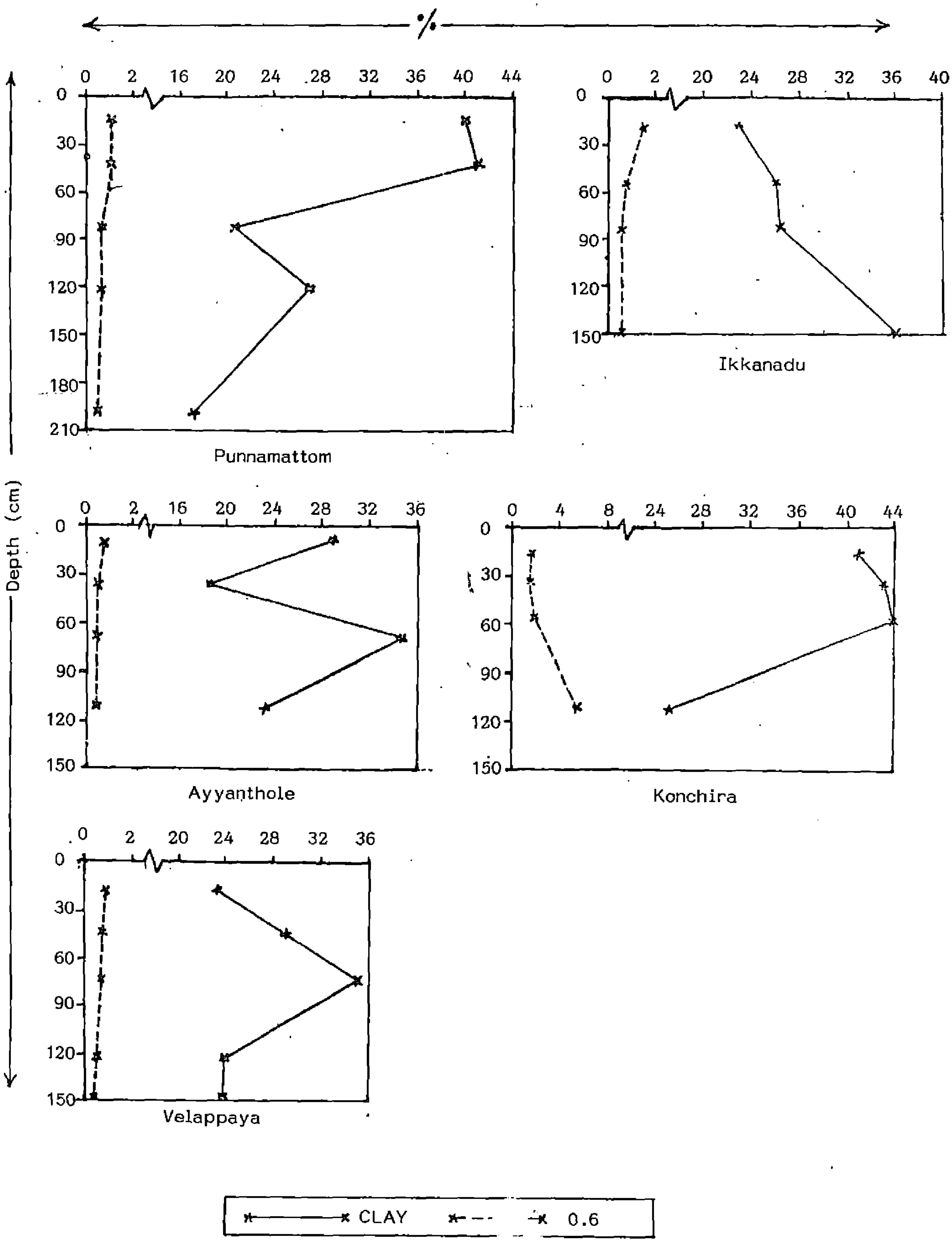

Table 7. Soil reaction, electrical conductivity and C/N ratio of soil

Soil series and depth (cm)		Soil reaction (1:2.5)	Electrical conductivity (mmhos/cm) (1:2.0)	Exchange acidity (me/100 g)	C (%)	C/N
1		2	3	4	5	6
Thodupuzha						
1	0-22	6.00	0.085	0.77	1.00	7.14
2	22-52	5.25	0.058	1.45	0.99	9.00
3	52-91	5.20	0.034	1.16	0.61	7.62
4	91-119	4.70	0.094	1.26	0.61	7.62
5	119-180	4.95	0.035	0.77	0.43	7.16
Mulamthuruthy						
6	0-15	5.50	0.012	0.77	0.76	9.50
7	15-42	5.70	0.023	0.40	0.33	6.60
8	42-60	6.00	0.025	0.20	0.33	6.60
9	60-94	6.00	0.014	0.40	0.26	6.50
10	94-150	6.00	0.012	0.30	0.24	6.00
Kothamangalam						
11	0-14	5.20	0.011	1.45	1.34	9.57
12	14-34	5.60	0.012	0.77	0.67	9.57
13	34-67	5.40	0.013	0.48	0.44	8.80
14	67-107	5.60	0.012	0.58	0.24	4.80
15	107-150	5.50	0.011	1.06	0.24	6.00

Contd.

Table 7. Continued

1		2	3	4	5	6
Punnamattom						
16	0-14	5.50	0.023	1.16	1.00	7.14
17	14-42	5.10	0.023	1.74	0.99	9.00
18	42-84	5.30	0.012	0.77	0.61	7.62
19	84-122	5.70	0.012	0.87	0.61	7.62
20	122-200	5.40	0.023	0.77	0.43	7.16
Ikkanadu						
21	0-19	6.00	0.200	1.20	1.56	9.76
22	19-54	6.00	0.245	1.30	0.82	6.83
23	54-85	5.50	0.150	1.30	0.67	9.57
24	85-150	5.90	0.035	1.30	0.65	10.83
Ayyanthole						
25	0-10	5.20	0.234	1.20	0.73	12.13
26	10-35	5.70	0.112	1.10	0.50	10.00
27	35-70	6.50	0.120	1.10	0.44	8.80
28	70-110	7.00	0.130	1.10	0.43	10.73
Konchira						
29	0-15	5.15	0.350	1.20	1.62	11.57
30	15-33	5.15	0.300	1.48	1.47	11.30
31	33-57	5.00	0.300	2.48	1.80	10.58
32	57-110^{+}	3.00	0.330	9.49	5.45	24.77

Contd.

Table 7. Continued

1		2	3	4	5	6
Velappaya						
33	0-18	5.50	0.204	1.40	0.76	8.44
34	18-43	5.50	0.130	1.30	0.70	7.77
35	43-85	5.50	0.060	1.30	0.70	8.75
36	85-122	5.00	0.150	1.20	0.50	7.14
37	122-150+	5.75	0.035	1.20	0.42	8.40

Table 8. Soil reaction, electrical conductivity and C/N ratio of soils, mean and range values

Series name	Soil reaction (1:2.5)	Electrical conductivity (mmhos/cm) (1:2.0)	Exchange acidity me/100 g	C (%)	C/N
Thodupuzha	4.70-6.00 (5.22)	0.034-0.094 (0.061)	0.77-1.45 (1.08)	0.43-1.00 (0.73)	7.14-9.00 (7.70)
Mulamthuruthy	5.50-6.00 (5.84)	0.012-0.025 (0.017)	0.20-0.77 (0.41)	0.24-0.76 (0.38)	6.00-9.57 (7.04)
Kothamangalam	5.20-5.60 (5.45)	0.011-0.013 (0.012)	0.48-1.45 (0.86)	0.24-1.34 (0.58)	4.8 -9.57 (7.74)
Punnamattom	5.10-5.70 (5.4)	0.012-0.023 (0.018)	0.77-1.74 (1.06)	0.43-1.00 (0.73)	7.14-9.00 (7.77)
Ikkanadu	5.50-6.00 (5.85)	5.035-0.246 (0.157)	1.2 -1.30 (1.27)	0.65-1.56 (0.92)	6.83-10.83 (9.24)
Ayyanthole	5.20-7.00 (6.10)	0.112-0.234 (0.149)	1.10-1.20 (1.12)	0.43-0.73 (0.52)	8.8 -12.13 (10.41)
Konchira	3.00-5.15 (4.75)	0.30-0.35 (0.32)	1.20-9.49 (3.66)	1.47-5.45 (2.58)	10.58-24.77 (14.55)
Velappaya	5.0-5.75 (5.45)	0.035-0.204 (0.115)	1.20-1.40 (1.28)	0.42-0.76 (0.61)	7.15-8.75 (8.1)

The exchange acidity was maximum (1.74) me/100 g in Punnamattom series (No.17) and minimum (0.77) me/100 g in Thodupuzha and Punnamattom series (No.1, 5 and 20) for dry lands, but for wet lands, it varied from 0.20 me/100 g in Mulamthuruthy series (No.8) to 9.49 me/100 g in Konchira series (No.32). The exchange acidity tend to increase with depth in Ikkanadu and Konchira series, while decreasing trend was noted in Ayyanthole and Velappaya series.

The organic carbon content of soils varied from 0.42 per cent for Velappaya series (No.37) to 1.00 per cent for Punnamattom and Thodupuzha series (No.1 and 16) for dry land series. In the case of wet land soils, it ranged from 0.24 per cent in Mulamthuruthy and Kothamanagalam series (No.10, 14 and 15) to 5.45 per cent in Konchira series (No.32). A steady decrease with depth was observed in all the soils except in the Konchira series where it showed the highest value in the lower most horizon.

The C/N ratio ranged from 7.14 in Thodupuzha and Velappaya series (No.1 and 36) to 9.00 in Thodupuzha and Punnamattom series (No.2 and 17) in the case of dry lands but in the case of wet lands, it varied from 4.8 in Kothamangalam series (No.14) to 24.77 in Konchira series (No.32). The C/N ratio showed a steady decrease with depth in Mulamthuruthy series only.

4.2. Total nutrient content of the soils

The total nutrient content of the soils, the mean and range values for profiles are given in Table 9 and 10 respectively.

The total nitrogen content varied from 0.05 per cent in Velappaya series (No.37) to 0.14 per cent in Punnamattom series (No.1 and 16) for dry lands, but for wet lands, it varied from 0.04 per cent in Mulamthuruthy, Kothamangalam and Ayyanthole series (No.9, 10, 15 and 28) to 0.22 per cent in Konchira series (No.32). A steady decrease with depth was noticed in all series except in Konchira series as in the case of carbon content, where it showed the highest value in the lowest horizon.

The total P_2O_5 content varied from 0.034 per cent in Thodupuzha series (No.2) to 0.16 per cent in Punnamattom series (No.17) for dry lands but for wet lands, it ranged from 0.01 per cent in Konchira series (No.30) to 0.09 per cent in Ayyanthole series (No.25). Irregular pattern in the distribution of P_2O_5 with depth was a feature showed in all the soil series under investigation.

The total K_2O content ranged from 0.08 per cent in Punnamattom series (No.18) to 0.88 per cent in Velappaya series (No.33) for dry lands, but for wet lands it varied from 0.11 per cent in Kothamangalam series (No.14) to 1.1 per cent in Ayyanthole series (No.26). The K_2O content showed a decreasing trend with depth

Table 9. Total nutrient content of soils (per cent on whole soils basis)

Soil series and depth (cm)		N	P_2O_5	K_2O	CaO	MgO	Na_2O	Fe_2O_3
1		2	3	4	5	6	7	8
Thodupuzha								
1	0-22	0.14	0.035	0.70	0.19	0.13	0.017	4.10
2	22-52	0.11	0.034	0.42	0.13	0.14	0.014	8.00
3	52-91	0.08	0.041	0.32	0.12	0.08	0.014	7.80
4	91-119	0.08	0.043	0.44	0.16	0.08	0.018	5.40
5	119-180	0.06	0.037	0.44	0.10	0.06	0.018	6.00
Mulamthuruthy								
6	0-15	0.08	0.031	0.25	0.20	0.15	0.420	1.20
7	15-43	0.05	0.034	0.28	0.17	0.13	0.045	1.50
8	43-60	0.05	0.040	0.32	0.13	0.09	0.070	4.20
9	60-94	0.04	0.037	0.31	0.20	0.06	0.030	4.00
10	94-150	0.04	0.035	0.32	0.20	0.20	0.040	7.20
Kothamangalam								
11	0-14	0.14	0.075	0.94	0.08	0.08	0.075	7.80
12	14-34	0.07	0.037	0.26	0.05	0.08	0.060	5.00
13	34-67	0.05	0.056	0.25	0.11	0.05	0.060	2.80
14	67-107	0.05	0.037	0.11	0.07	0.05	0.070	2.80
15	107-150	0.04	0.037	0.82	0.12	0.05	0.060	1.80

Contd.

Table 9. Continued

1		2	3	4	5	6	7	8
Punnamattom								
16	0-14	0.14	0.15	0.42	0.16	0.08	0.08	6.50
17	14-43	0.11	0.16	0.71	0.14	0.09	0.05	7.70
18	43-84	0.08	0.15	0.08	0.08	0.04	0.07	5.70
19	84-122	0.08	0.11	0.55	0.09	0.04	0.06	3.00
20	122-200	0.06	0.14	0.47	0.05	0.02	0.05	4.60
Ikkanadu								
21	0-19	0.16	0.056	0.88	0.07	0.04	0.09	0.50
22	19-54	0.12	0.056	0.88	0.06	0.03	0.15	1.50
23	54-85	0.07	0.037	0.78	0.05	0.05	0.09	2.00
24	85-150	0.06	0.075	0.67	0.05	0.03	0.08	3.00
Ayyanthole								
25	0-10	0.06	0.090	0.60	0.04	0.03	0.04	3.20
26	10-35	0.05	0.037	1.10	0.03	0.04	0.08	6.30
27	35-70	0.05	0.075	0.73	0.05	0.02	0.04	4.50
28	70-110	0.04	0.056	0.74	0.04	0.02	0.10	4.50
Konchira								
29	0-15	0.14	0.025	0.64	0.07	0.08	0.17	4.01
30	15-33	0.13	0.010	0.53	0.06	0.08	0.21	5.62
31	33-57	0.17	0.020	0.20	0.04	0.05	0.21	3.21
32	57-110	0.22	0.020	0.17	0.04	0.22	0.16	3.12

Contd.

Table 9. Continued

1		2	3	4	5	6	7	8
Velappaya								
33	0-18	0.09	0.09	0.88	0.12	0.28	0.05	5.12
34	18-43	0.09	0.09	0.23	0.09	0.14	0.06	3.61
35	43-85	0.08	0.09	0.37	0.16	0.21	0.07	7.07
36	85-122	0.07	0.075	0.40	0.06	0.19	0.05	5.32
37	122-150	0.05	0.15	0.23	0.06	0.14	0.07	12.57

Table 10. Total nutrient content of soils, mean and range values for profiles, %

Series name	N	P_2O_5	K_2O	Ca	MgO	Na_2O	Fe_2O_3
Thodupuzha	0.06-0.14 (0.09)	0.034-0.043 (0.038)	0.30-0.70 (0.46)	0.10-0.19 (0.14)	0.06-0.14 (0.09)	0.014-0.018 (0.016)	4.10-8.00 (6.66)
Mulamthuruthy	0.04-0.08 (0.05)	0.031-0.040 (0.035)	0.25-0.32 (0.29)	0.13-0.20 (0.18)	0.06-0.2 (0.12)	0.03-0.42 (0.121)	1.20-7.20 (3.62)
Kothamangalam	0.04-0.14 (0.07)	0.037-0.075 (0.048)	0.11-0.94 (0.47)	0.07-0.12 (0.08)	0.05-0.08 (0.06)	0.06-0.075 (0.065)	1.80-7.80 (4.04)
Punnamattom	0.06-0.14 (0.09)	0.11-0.16 (0.14)	0.08-0.71 (0.44)	0.05-0.14 (0.09)	0.02-0.09 (0.05)	0.05-0.08 (0.06)	3.00-7.70 (5.50)
Ikkanadu	0.06-0.16 (0.10)	0.037-0.075 (0.056)	0.67-0.88 (0.80)	0.05-0.07 (0.06)	0.03-0.05 (0.04)	0.08-0.15 (0.10)	0.50-3.00 (1.75)
Ayyanthole	0.04-0.06 (0.05)	0.037-0.09 (0.064)	0.60-1.1 (0.79)	0.03-0.05 (0.04)	0.02-0.04 (0.03)	0.04-0.10 (0.06)	3.2-6.3 (4.62)
Konchira	0.13-0.22 (0.16)	0.01-0.025 (0.018)	0.17-0.64 (0.38)	0.04-0.07 (0.05)	0.05-0.22 (0.10)	0.16-0.26 (0.18)	3.12-5.62 (3.99)
Velappaya	0.05-0.09 (0.07)	0.075-0.15 (0.099)	0.23-0.88 (0.42)	0.06-0.16 (0.09)	0.14-0.28 (0.19)	0.05-0.07 (0.06)	3.61-12.57 (6.81)

in Ikkanadu and Konchira series. Surface horizon showed accumulation in the case of Kothamangalam, Thodupuzha, Konchira and Velappaya series.

The lowest and highest content for CaO was recorded for the Punnamattom series (No.20) and Thodupuzha series (No.1) with values of 0.05 per cent and 0.19 per cent respectively. In the soils of wet lands, it varied from 0.03 per cent in Ayyanthole series (No.26) to 0.20 per cent in Mulamthuruthy series (No.6, 9 and 10).

The content of MgO ranged from 0.02 per cent in Punnamattom series (No.20) to 0.28 per cent in Velappaya series (No.33) in the case of dry lands, but for wet lands, it ranged from 0.02 per cent in Ayyanthole series (No.27 and 28) to 0.22 per cent in Konchira series (No.32). The MgO showed a decreasing trend with depth in the case of Ayyanthole series only.

The Fe_2O_3 content varied from 3.00 per cent in Punnamattom series (No.19) to 12.57 per cent in Velappaya series (No.37) for dry lands but for wet lands, it ranged from 0.50 per cent in Ikkanadu series (No.21) to 7.80 per cent in Kothamangalam series (No.11). A steady increase in Fe_2O_3 content with depth was noticed in Ikkanadu series only.

In respect of Na_2O its content ranged from 0.014 per cent in Thodupuzha series (No.2 and 3) to 0.08 per cent in Punnamattom series (No.16) in the case of dry lands but for wet lands, it varied from 0.03 per cent in Mulamthuruthy series (No.9) to 0.42 per cent again in Mulamthuruthy series (No.6).

5. Cation exchange properties

Cation exchange properties and exchangeable cations of the soils are given in Table 11. Mean and range values are presented in Table 12.

5.1. Cation exchange capacity

NH_4OAc CEC varied from 6.95 me/100 g in Thodupuzha series (No.2) to 16.90 me/100 g in Punnamattom series (No.18) for the soils of dry lands, but in the case of wet land soils, it varied from 1.50 me/100 g in Mulamthuruthy series (No.7) to 21.65 me/100 g in Konchira series (No.32). The CEC was found to decrease with depth in Ikkanadu series, while it showed an increasing trend with depth in Konchira series.

The CEC (NH_4OAc)/100 g clay varied from 24.20 me/100 g in Velappaya series (No.35) to 78.60 me/100 g in Punnamattom series (No.18) in the case of dry lands, but in the case of wet lands, it ranged from 7.12 me/100 g in Mulamthuruthy series (No.7) to 86.60 me/100 g in Konchira series (No.32). Within the profile, this value found to decrease with depth in Ayyanthole series only.

5.2. Exchangeable cations

Calcium formed the predominant exchangeable cation and varied from 0.82 me/100 g soil in Thodupuzha series (No.5) to

Table 11. Cation exchange properties of soils

Series name and depth (cm)	Exchangeable cations me/100 g soil				Sum of bases (me/100 g)	CEC (NH_4OAc pH7) me/100 g soil	CEC (NH_4OAc) me/100 g clay	Base saturation (%) (NH_4OAc pH7)
	Ca	Mg	K	Na				
1	2	3	4	5	6	7	8	9
Thodupuzha								
1 0-22	1.10	0.55	0.48	0.13	2.26	8.20	46.85	27.56
2 22-52	1.21	0.16	0.25	0.17	1.79	6.95	29.57	25.75
3 52-91	1.10	0.33	0.15	0.25	1.83	7.80	34.66	23.46
4 91-119	1.04	0.11	0.18	0.11	1.44	8.20	27.33	17.56
5 119-180	0.82	0.27	0.17	0.13	1.39	7.50	28.84	18.53
Mulamthuruthy								
6 0-15	0.77	0.55	0.05	0.12	1.49	2.75	17.18	54.18
7 15-43	0.80	0.30	0.05	0.10	1.25	1.50	7.12	83.33
8 43-60	1.26	0.38	0.10	0.23	1.97	2.15	10.23	91.66
9 60-94	1.48	0.71	0.14	0.28	2.61	3.60	16.21	72.50
10 94-150	1.87	0.66	0.18	0.15	2.86	4.00	25.25	71.50
Kothamangalam								
11 0-14	1.32	0.05	0.09	0.12	1.58	10.75	45.74	14.69
12 14-34	0.93	0.44	0.04	0.12	1.53	8.75	46.05	17.48
13 34-67	0.93	0.16	0.04	0.22	1.35	8.30	83.00	16.23
14 67-107	1.26	0.23	0.07	0.13	1.68	8.90	74.16	18.87
15 107-150	1.04	0.05	0.05	0.09	1.23	11.15	43.7	11.03

Contd.

Table 11. Continued

1		2	3	4	5	6	7	8	9
Punnamattom									
16	0-14	4.34	0.38	0.02	0.03	4.77	11.50	28.75	41.47
17	14-43	3.40	0.11	0.07	0.06	3.64	11.50	28.04	31.91
18	43-84	4.18	0.55	0.27	0.11	5.11	16.90	78.60	30.23
19	84-122	3.6	0.22	0.04	0.19	4.41	11.65	42.36	37.85
20	122-200	4.07	0.44	0.04	0.02	4.57	7.55	43.14	60.52
Ikkanadu									
21	0-19	4.80	2.30	0.30	0.06	7.46	9.70	42.17	76.90
22	19-54	3.68	1.15	0.08	0.02	4.93	9.70	36.80	50.82
23	54-85	3.80	0.16	0.05	0.01	4.02	8.85	33.4	45.42
24	85-150	3.41	1.15	0.06	0.05	4.67	8.15	22.26	57.30
Ayyanthole									
25	0-10	1.37	0.16	0.10	0.15	1.78	3.60	12.41	49.44
26	10-35	2.64	0.05	0.10	0.17	2.96	4.65	25.13	63.65
27	35-70	2.59	0.71	0.17	0.20	3.67	6.20	17.46	59.19
28	70-110	3.00	1.92	1.50	0.18	2.00	3.65	15.53	54.80
Konchira									
29	0-15	1.76	0.90	0.28	1.00	3.94	7.15	17.43	55.10
30	15-33	1.48	0.80	0.21	1.07	3.56	9.85	22.90	36.14
31	33-57	2.14	1.15	0.22	1.07	4.58	9.85	22.38	46.49
32	57-110	2.75	0.66	0.13	1.70	5.24	21.65	86.60	24.20

Contd.

Table 11. Continued

1		2	3	4	5	6	7	8	9
Velappaya									
33	0-18	2.14	0.55	0.05	0.07	2.81	12.50	54.8	22.44
34	18-43	2.42	0.83	0.01	0.03	2.79	9.70	33.4	28.76
35	43-85	3.13	0.71	0.07	0.06	3.97	8.45	24.2	46.98
36	85-122	3.41	0.61	0.02	0.02	4.05	9.10	38.0	44.05
37	122-150	2.47	0.55	0.34	0.07	3.43	10.05	42.6	34.12

Table 12. Cation exchange properties of soils, mean and range values for profiles

Series name	Exchangeable cations me/100 g soil				Some of base me/100 g	CEC (NH_4OAc pH7) me/100 g soil	CEC (NH_4OAc) me/100 g clay	Base saturation (%) (NH_4OAc pH7)
	Ca	Mg	K	Na				
Thodupuzha	0.82–1.21 (1.05)	0.11–0.55 (0.28)	0.15–0.48 (0.24)	0.11–0.25 (0.16)	1.39–2.26 (1.74)	6.95–8.20 (7.73)	27.33–46.85 (33.45)	17.56–27.56 (22.50)
Mulamthuruthy	0.77–1.87 (1.23)	0.30–0.71 (0.52)	0.05–0.18 (0.11)	0.10–0.28 (0.17)	1.25–2.86 (2.03)	1.50–4.00 (2.80)	7.12–25.25 (15.19)	54.18–91.62 (74.68)
Kothamangalam	0.93–1.32 (1.09)	0.05–0.44 (0.18)	0.04–0.09 (0.06)	0.09–0.22 (0.13)	1.23–1.68 (1.47)	8.30–11.15 (9.57)	43.70–83.00 (58.54)	11.03–18.87 (15.66)
Punnamattom	3.40–4.34 (3.99)	0.11–0.55 (0.34)	0.02–0.27 (0.09)	0.02–0.19 (0.08)	3.64–4.77 (4.50)	7.55–16.90 (11.82)	28.04–78.60 (44.17)	30.23–60.52 (40.4)
Ikkanadan	3.41–4.80 (3.92)	0.16–2.30 (1.19)	0.05–0.30 (0.12)	0.01–0.06 (0.03)	4.02–7.46 (5.27)	8.15–9.70 (9.1)	22.26–42.17 (33.55)	45.42–76.90 (57.61)
Ayyanthole	1.37–3.00 (2.4)	0.05–1.92 (0.71)	0.10–1.50 (0.46)	0.15–0.20 (0.17)	1.78–3.67 (2.60)	3.60–6.20 (4.52)	12.41–25.13 (17.63)	49.44–63.65 (56.77)
Konchira	1.48–2.75 (2.03)	0.55–1.15 (0.87)	0.13–0.28 (0.21)	1.00–1.70 (1.21)	3.56–5.24 (4.33)	7.15–21.65 (12.12)	17.43–86.60 (37.32)	24.20–55.10 (40.48)
Velappaya	2.14–3.41 (2.71)	0.33–0.71 (0.56)	0.01–0.34 (0.09)	0.02–0.07 (0.05)	2.79–4.05 (3.41)	8.45–12.5 (9.96)	24.20–54.80 (38.60)	22.44–46.98 (35.27)

4.34 me/100 g in Punnamattom series (No.16) in the case of dry lands but in the case of wet lands, it varied from 0.74 me/100 g in Mulamthuruthy series (No.6) to 3.00 me/100 g in Ayyanthole series (No.28).

The second major exchangeable cation was magnesium and it varied from 0.11 me/100 g in Thodupuzha and Punnamattom series (No.4 and 17) to 0.71 me/100 g in Velappaya series (No.35) for dry lands and for wet lands, it varied from 0.05 me/100 g in Kothamangalam and Ayyanthole series (No.11, 15 and 26) to 2.30 me/100 g in Ikkanadu series (No.21).

The exchangeable potassium content varied from 0.01 me/100 g in Velappaya series (No.34) to 0.48 me/100 g in Thodupuzha series (No.1) for dry lands but for wet lands, it varied from 0.04 me/100g in Kothamangalam series (No.12 and 13) to 1.50 me/100 g in Ayyanthole series (No.28). It's content increased with depth in Mulamthuruthy and Ayyanthole series.

The exchangeable sodium content varied from 0.02 me/100 g in Punnamattom and Velappaya series (No.20 and 36) to 0.25 me/100 g in Thodupuzha series (No.3) for dry lands but for wet lands, it ranged from 0.01 me/100 g in Ikkanadu series (no.23) to 1.70 me/100 g in Konchira series (No.32). It's content increased with depth in Konchira series only.

Sum of bases recorded highest value (4.77 me/100 g) in Punnamattom series (No.16) and lowest value (1.39 me/100 g) in Thodupuzha series (No.5) for dry lands but for wet lands, the highest value recorded (7.66 me/100 g) in Ikkanadu series (No.21) and lowest value

(1.25 me/100 g) in Mulamthuruthy series (No.7). It's content increased with depth in Konchira series only.

Percentage base saturation by ammonium acetate method varied from 17.56 per cent in Thodupuzha series (No.4) to 60.52 per cent in Punnamattom series (No.20) for dry lands but for wet lands, it ranged from 11.03 per cent in Kothamangalam series (No.15) to 91.62 per cent in Mulamthuruthy series (No.8).

6. Extractable iron and active iron ratio

The iron oxide fractions and active iron ratio are presented in Table 13 and mean and range values are given in Table 14. Depth wise distribution of iron fractions are given in Fig. 4.

The Fe_d ranged from 0.50 per cent in Velappaya series (No.34) to 2.3 per cent again in Velappaya series (No.37) for dry lands but for wet lands, it varied from 0.23 per cent in Ikkanadu series (No.21) to 2.10 per cent in Mulamthuruthy series (No.10).

The Fe_o varied from 0.12 per cent in Thodupuzha series (No.1) to 1.10 per cent in Velappaya series (No.37) for dry lands but for wet lands, it varied from 0.09 per cent in Ikkanadu series (No.22). to 1.12 per cent in Konchira series (No.32). It's content showed an increase with depth in the case of Mulamthuruthy series only.

The Fe_d expressed as percentage of total iron referred to as "degree of freeness of iron oxide" was highest (49.00) in Punnamattom series (No.19) and lowest (12.15) in Velappaya series (No.33)

Fig.4. Distribution of total iron and its fractions in soil profiles

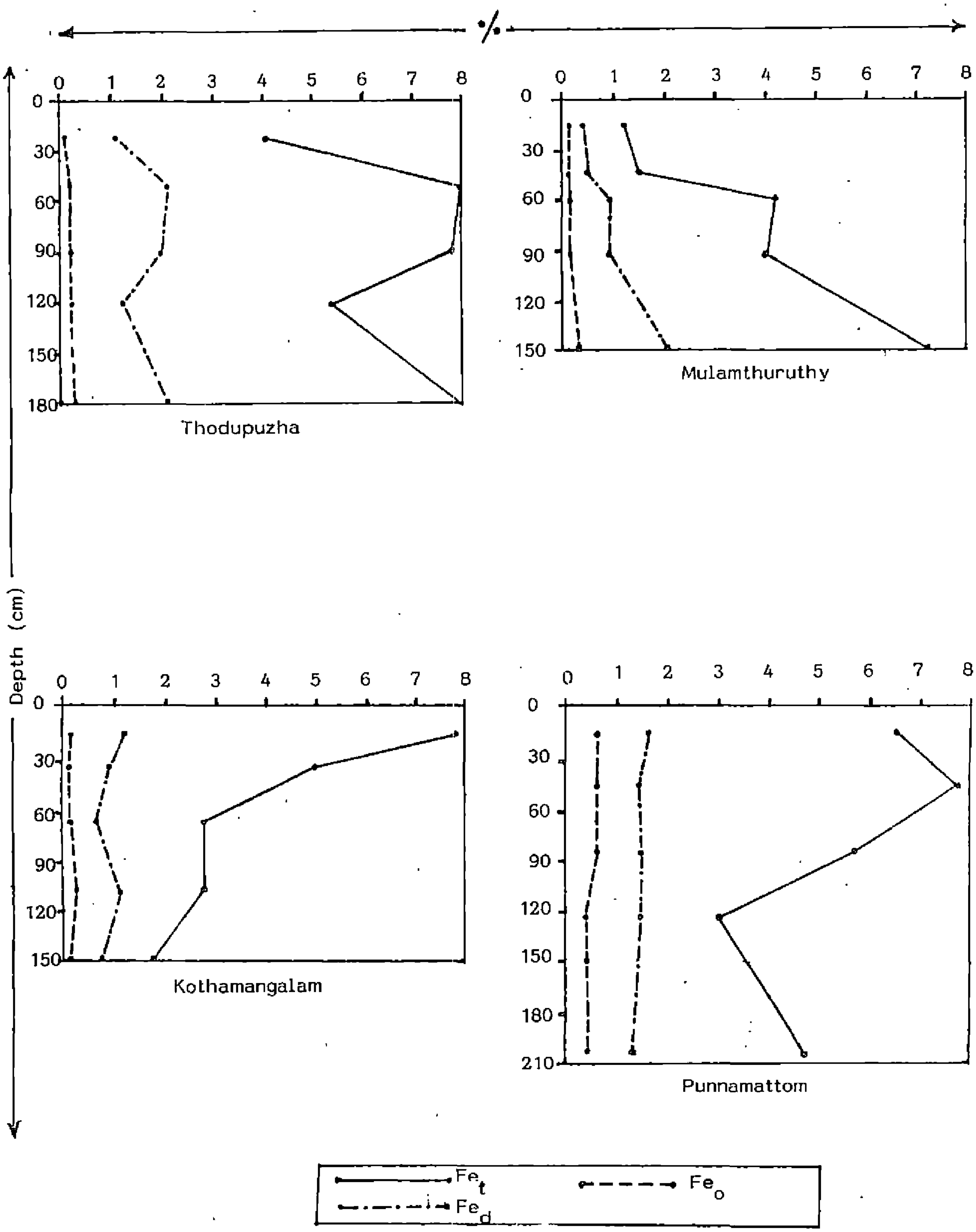

Fig.4. Continued

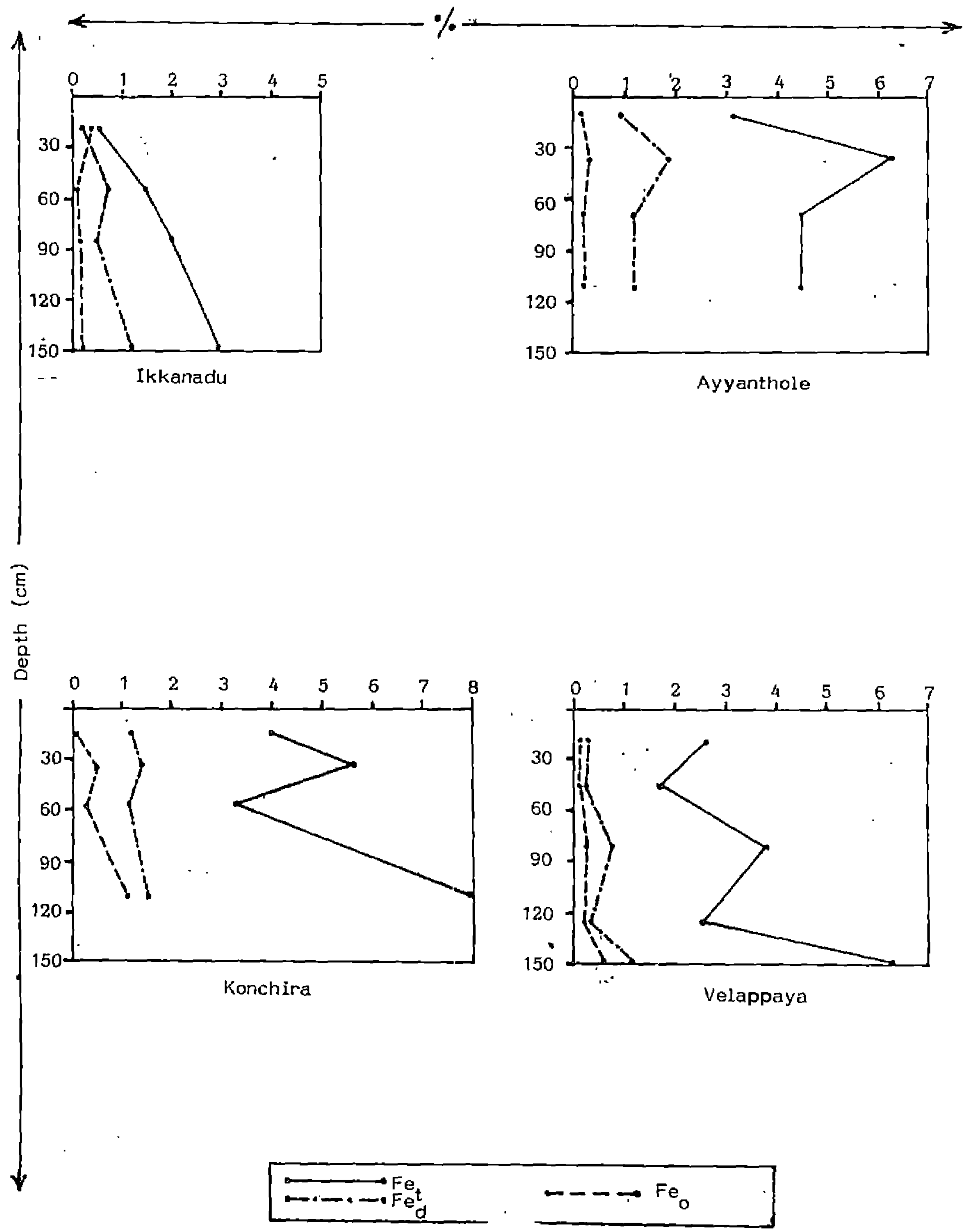

Table 13. Iron oxide fractions in soils

Series name and depth (cm)	% Fe_2O_3			$\frac{Fe_d \times 100}{Fe_t}$	Active iron ratio Fe_o/Fe_d	Fe_d/clay	Fe_d/silt
	Fe_t	Fe_d	Fe_o				
1	2	3	4	5	6	7	8
Thodupuzha							
1 0-22	4.1	1.12	0.12	27.3	0.11	0.06	0.013
2 22-52	8.0	2.12	0.22	26.5	0.10	0.09	0.028
3 52-91	7.8	2.00	0.23	25.64	0.11	0.08	0.026
4 91-119	5.4	1.25	0.20	23.14	0.16	0.04	0.018
5 119-180	8.0	2.10	0.25	26.25	0.12	0.08	0.028
Mulamthuruthy							
6 0-15	1.2	0.4	0.13	33.3	0.32	0.03	0.004
7 15-43	1.5	0.5	0.14	33.3	0.28	0.03	0.006
8 43-60	4.2	0.93	0.18	22.14	0.20	0.04	0.011
9 60-94	4.0	0.91	0.18	22.75	0.20	0.04	0.011
10 94-150	7.2	2.10	0.36	29.16	0.17	0.13	0.025
Kothamangalam							
11 0-14	7.8	1.25	0.13	16.02	0.10	0.05	0.016
12 14-34	5.0	0.97	0.12	19.40	0.12	0.05	0.012
13 34-67	2.8	0.66	0.16	23.57	0.24	0.06	0.007
14 67-107	2.8	1.12	0.25	40.00	0.22	0.09	0.012
15 107-150	1.8	0.67	0.10	37.22	0.15	0.03	0.019

Contd.

Table 13. Continued

1		2	3	4	5	6	7	8
Punnamattom								
16	0-14	6.5	1.6	0.62	24.61	0.38	0.04	0.027
17	14-43	7.7	1.47	0.61	19.09	0.41	0.03	0.025
18	43-84	5.7	1.47	0.61	25.78	0.41	0.07	0.018
19	84-122	3.0	1.47	0.37	49.00	0.25	0.04	0.020
20	122-200	4.6	1.30	0.40	28.26	0.30	0.07	0.016
Ikkanadu								
21	0-19	0.5	0.23	0.37	46.0	0.16	0.01	0.003
22	19-54	1.5	0.70	0.09	46.66	0.13	0.02	0.01
23	54-85	2.0	0.50	0.12	25.00	0.24	0.02	0.006
24	85-150	3.0	1.25	0.19	41.66	0.15	0.03	0.02
Ayyanthole								
25	0-10	3.2	0.91	0.15	28.48	0.16	0.03	0.013
26	10-35	6.3	1.87	0.31	29.68	0.16	0.10	0.023
27	35-70	4.5	1.20	0.23	26.66	0.19	0.03	0.02
28	70-110	4.5	1.23	0.22	27.33	0.17	0.05	0.016
Konchira								
29	0-15	4.0	1.20	0.04	30.00	0.33	0.03	0.020
30	15-33	5.6	1.45	0.5	25.89	0.34	0.03	0.025
31	33-57	3.2	1.15	0.3	35.93	0.26	0.02	0.020
32	57-110	8.0	1.52	1.12	18.75	0.73	0.06	0.020

Contd.

Table 13. Continued

1		2	3	4	5	6	7	8
Velappaya								
33	0-18	5.1	0.62	0.3	12.15	0.48	0.02	0.008
34	18-43	3.6	0.50	0.2	13.88	0.40	0.02	0.007
35	43-85	7.5	1.65	0.5	22.00	0.30	0.04	0.026
36	85-122	5.3	0.70	0.4	13.20	0.57	0.03	0.01
37	122-150	12.5	2.30	1.10	18.4	0.47	0.10	0.03

Table 14. Iron oxide fractions in soils, mean and range values for profiles

Soil series	Fe_t %	Fe_d %	Fe_o %	$\frac{Fe_d \times 100}{Fe_t}$	Fe_o/Fe_d	Fe_d/clay	$\frac{Fe_d}{\text{Silt + sand}}$
Thodupuzha	4.10-8.00 (6.58)	1.12-2.12 (1.71)	0.12-0.25 (0.20)	23.14-27.3 (25.76)	0.10-0.16 (0.12)	0.04-0.09 (0.07)	0.013-0.028 (0.022)
Mulamthuruthy	1.2-7.20 (3.62)	0.40-2.10 (0.96)	0.13-0.36 (0.19)	22.14-33.3 (28.13)	0.20-0.32 (0.23)	0.03-0.13 (0.05)	0.004-0.025 (0.011)
Kothamangalam	1.8 -7.80 (4.04)	0.66-1.25 (0.93)	0.10-0.25 (0.15)	16.02-40.00 (27.24)	0.10-0.24 (0.16)	0.03-0.09 (0.05)	0.007-0.016 (0.01)
Punnamattom	3.0 -7.7 (5.5)	1.30-1.60 (1.46)	0.37-0.62 (0.52)	19.09-49.00 (29.34)	0.26-0.41 (0.35)	0.03-0.07 (0.05)	0.016-0.027 (0.021)
Ikkanadu	0.5 -3.0 (1.75)	0.23-1.25 (0.67)	0.09-0.37 (0.19)	25.00-46.66 (39.83)	0.13-0.24 (0.17)	0.01-0.03 (0.02)	0.003-0.02 (0.009)
Ayyanthole	3.2 -6.3 (4.62)	0.91-1.87 (1.30)	0.15-0.31 (0.23)	26.66-29.68 (28.04)	0.16-0.19 (0.17)	0.03-0.10 (0.05)	0.013-0.023 (0.018)
Konchira	3.2 -8.00 (5.2)	1.15-1.52 (1.33)	0.3 -1.12 (0.58)	18.75-35.93 (27.64)	0.26-0.73 (0.41)	0.02-0.06 (0.03)	0.02 -0.025 (0.021)
Velappaya	3.6 -12.5 (6.8)	0.50-2.3 (1.15)	0.2 -1.10 (0.05)	12.15-22.00 (15.92)	0.30-0.57 (0.44)	0.02-0.10 (0.04)	0.007-0.03 (0.015)

for dry lands but for wet lands, it varied from 16.02 in Kothamangalam series (No.11) to 46.66 in Ikkanadu series (No.22).

The ratio of Fe_o/Fe_d termed as active iron ratio ranged from 0.10 in Thodupuzha series (No.2) to 0.57 in Velappaya series (No.36) for dry lands but for wet lands, it ranged from 0.10 in Kothamangalam series (No.11) to 0.73 in Konchira series (No.32). A decreasing trend with depth was observed in Mulamthuruthy series only.

The ratio of Fe_d/clay was lowest (0.02) in Velappaya series (No.33 and 34) and highest (0.10) again Velappaya series (No.37) for dry lands, but for wet lands, it varied from 0.01 in Ikkanadu series (No.21) to 0.13 in Mulamthuruthy series (No.10). It tends to increase with depth in the case of Mulamthuruthy and Ikkanadu series only.

Fe_d/silt + sand varied rom 0.007 in Velappaya series (No.34) to 0.03 again in Velappaya series (No.37) for dry lands. But for wet lands, it varied from 0.003 in Ikkanadu series (No.21) to 0.025 in Mulamthuruthy and Konchira series (No.10 and 30). It tend to increase with depth in the case of Mulamthuruthy series only.

7. Analysis of surface samples

7.1. Mechanical composition

The mechanical composition of surface samples are given in Table 15.

The textural class of the surface soils (0-20 cm) showed that the Punnamattom and Thodupuzha series had predominantly silt texture varying from loam to silty clay loam. In the Velappaya series also, the texture varied from silty loam to silty clay loam. In respect of the wet land also, silty texture was predominant with silty clay loam to silty clay noted in Kothamangalam and Ikkanadu series. Mulamthuruthy and Ayyanthole series were found with textures ranging from loamy sand to silty loam. Konchira series had more clayey texture grading from silty clay loam to silty clay.

7.2. Soil reaction, electrical conductivity and phosphorus fixing capacity

The soil reaction, electrical conductivity and phosphorus fixing capacity of soils are given in Table 16 and mean and range values in Table 17.

The soil reaction in general was acidic with pH values ranging from 5.30 in Punnamattom series (No.34) to 7.00 again in Punnamattom series (No.35) for dry lands but for wet lands, it ranged from 3.70 in Mulamthuruthy series (No.12) to 7.00 again in Mulamthuruthy series (No.14).

Table 15. Particle size distribution of soils (surface samples)

Soil series and sample No.		Coarse fragments (>2 mm) %	Size, class and particle diameter (mm)			Textural class
			Sand 2.0-0.02 %	Silt 0.02-0.002 %	Clay <0.002 %	
1		2	3	4	5	6
Thodupuzha	1	11.03	76.00	4.50	19.50	Loam
	2	29.00	56.00	4.00	28.00	Silty clay loam
	3	30.77	68.00	16.00	16.00	Silty loam
	4	29.33	80.00	4.50	15.50	Loam
	5	19.56	72.00	8.00	20.00	Silty loam
	6	36.33	64.00	8.00	28.00	Silty clay loam
	7	37.10	64.00	4.00	32.00	Silty clay loam
	8	28.57	84.00	4.00	12.00	Loam
	9	32.01	76.00	8.00	16.00	Loam
	10	34.56	62.00	6.00	32.00	Silty clay loam
Mulamthuruthy	11	12.44	88.00	4.00	8.00	Loamy sand
	12	13.50	92.00	4.00	4.00	Loamy sand
	13	15.50	92.00	4.00	4.00	Loamy sand
	14	20.50	88.00	4.00	8.00	Loamy sand
	15	21.40	80.00	4.00	16.00	Loam
	16	35.30	76.00	4.00	20.00	Loam

Contd.

Table 15. Continued

1		2	3	4	5	6
	17	24.06	60.00	8.00	32.00	Silty clay loam
	18	37.50	64.00	8.00	28.00	Silty clay loam
	19	21.62	76.00	8.00	16.00	Loam
	20	27.63	75.00	5.00	20.00	Loam
Kothamangalam	21	22.72	48.00	20.00	32.00	Silty clay loam
	22	25.00	52.00	8.00	40.00	Silty clay
	23	14.50	64.00	8.00	28.00	Silty clay loam
	24	31.25	64.00	6.00	30.00	Silty clay loam
	25	27.50	60.00	4.00	36.00	Silty clay loam
	26	15.50	56.00	14.00	30.00	Silty clay loam
	27	34.78	65.00	8.00	27.00	Silty clay loam
	28	31.21	65.00	6.00	29.00	Silty clay loam
	29	25.00	60.00	5.00	35.00	Silty clay loam
	30	29.91	84.00	6.00	30.00	Clay loam
Punnamattom	31	15.00	80.00	4.00	16.00	Loam
	32	14.50	64.00	16.00	20.00	Silty loam
	33	13.60	52.00	20.00	28.00	Silty clay loam
	34	12.50	64.00	8.00	28.00	Silty clay loam
	35	10.50	48.00	20.00	32.00	Silty clay loam
	36	13.23	68.00	12.00	20.00	Silty loam
	37	14.50	88.00	4.00	8.00	Loamy sand

Contd.

Table 15. Continued

1		2	3	4	5	6
	38	17.50	76.00	8.00	16.00	Loam
	39	14.32	76.00	12.00	20.00	Loam
	40	13.35	66.00	10.00	24.00	Silty loam
Ikkanadu	41	38.58	72.00	8.00	20.00	Silty loam
	42	33.59	62.00	26.00	12.00	Silty loam
	43	16.67	72.00	20.00	8.00	Silty loam
	44	16.67	54.00	10.00	36.00	Silty clay loam
	45	18.37	64.00	4.00	32.00	Silty clay loam
	46	17.07	54.00	8.00	38.00	Silty clay loam
	47	35.71	68.00	12.00	20.00	Silty loam
	48	32.00	70.00	16.00	14.00	Silty loam
	49	38.90	74.00	10.00	16.00	Silty loam
	50	26.42	67.00	12.00	21.00	Silty loam
Ayyanthole	51	26.67	88.00	8.00	4.00	Loamy sand
	52	20.00	78.00	12.00	10.00	Loamy sand
	53	17.24	84.00	8.00	8.00	Loamy sand
	54	23.08	88.00	2.00	10.00	Loamy sand
	55	16.67	90.00	2.00	8.00	Loamy sand
	56	15.07	66.00	6.00	28.00	Silty clay loam
	57	10.00	78.10	10.00	12.00	Loamy sand

Contd.

Table 15. Continued

1		2	3	4	5	6
	58	11.11	71.00	15.00	14.00	Silty loam
	59	14.29	74.00	10.00	16.00	Silty loam
	60	20.45	82.00	8.00	10.00	Loamy sand
Konchira	61	30.43	44.00	2.00	56.00	Silty clay
	62	41.24	56.00	4.00	40.00	Silty clay
	63	37.17	48.00	10.00	42.00	Silty clay
	64	39.39	62.00	2.00	36.00	Silty clay loam
	65	18.45	54.00	8.00	38.00	Silty clay loam
	66	36.57	52.00	12.00	36.00	Silty clay loam
	67	30.63	54.00	8.00	38.00	Silty clay loam
	68	30.00	55.00	8.00	37.00	Silty clay loam
	69	37.21	58.00	9.00	38.00	Silty clay loam
	70	42.57	50.00	9.00	41.00	Silty clay
Velappaya	71	41.67	62.00	4.00	34.00	Silty clay loam
	72	35.71	58.00	6.00	36.00	Silty clay loam
	73	33.33	58.00	6.00	36.00	Silty clay loam
	74	21.43	72.00	12.00	16.00	Silty loam
	75	33.33	72.00	8.00	20.00	Silty loam
	76	34.62	70.00	14.00	16.00	Silty loam
	77	37.02	68.00	14.00	18.00	Silty loam
	78	42.86	70.00	14.00	16.00	Silty loam
	79	36.91	56.00	10.00	32.00	Silty clay loam
	80	35.71	66.00	12.00	22.00	Silty loam

Table 16. Soil reaction, electrical conductivity and phosphorus fixing capacity (surface samples)

Series name	Sample No.	Soil reaction (1:2.5)	Electrical conductivity (1:2.0) mmhos/cm	Phosphorus fixing capacity mg P/100 g soil
1	2	3	4	5
Thodupuzha	1	5.5	0.050	100.05
	2	5.6	0.060	100.00
	3	5.7	0.040	95.50
	4	6.35	0.030	99.00
	5	6.00	0.070	73.50
	6	5.90	0.035	74.50
	7	6.00	0.041	75.00
	8	5.60	0.082	95.00
	9	5.50	0.075	90.00
	10	6.40	0.094	73.5
Mulamthuruthy	11	4.00	0.450	53.00
	12	3.70	0.580	55.00
	13	4.70	0.400	60.00
	14	7.00	0.164	62.00
	15	5.65	0.047	74.50
	16	5.60	0.023	65.00
	17	5.70	0.040	63.00
	18	5.60	0.140	75.00
	19	5.75	0.150	70.00
	20	5.60	0.117	95.00
Kothamangalam	21	5.50	0.025	55.00
	22	5.60	0.023	60.00
	23	5.70	0.024	57.00
	24	6.40	0.058	10.00
	25	6.30	0.023	35.00
	26	6.40	0.035	30.00
	27	6.50	0.041	35.00

Contd.

Table 16. Continued

1	2	3	4	5
	28	5.30	0.058	40.00
	29	4.75	0.060	50.00
	30	5.00	0.058	75.00
Punnamattom	31	6.50	0.134	67.00
	32	6.80	0.140	67.50
	33	6.00	0.150	100.00
	34	5.30	0.035	150.00
	35	7.00	0.330	82.50
	36	6.50	0.150	105.00
	37	6.30	0.160	100.00
	38	6.00	0.234	150.00
	39	6.10	0.150	99.00
	40	6.40	0.072	100.00
Ikkanadu	41	5.5	0.085	150.10
	42	5.9	0.082	155.20
	43	5.7	0.085	167.50
	44	6.1	0.094	187.50
	45	6.0	0.184	142.50
	46	5.75	0.094	135.00
	47	5.70	0.104	120.50
	48	6.10	0.130	111.70
	49	6.1	0.087	120.5
	50	6.3	0.058	135.00
Ayyanthole	51	5.70	0.110	85.00
	52	5.75	0.117	82.50
	53	5.70	0.115	86.00
	54	5.30	0.130	90.00
	55	6.00	0.047	90.00
	56	5.10	0.035	82.50
	57	5.15	0.065	55.60
	58	6.10	0.047	37.50
	59	6.15	0.055	44.50
	60	5.10	0.035	45.50

Contd.

Table 16. Continued

1	2	3	4	5
Konchira	61	4.45	0.180	91.00
	62	4.40	0.187	90.00
	63	4.50	0.156	92.00
	64	4.60	0.140	82.00
	65	4.50	0.175	67.50
	66	5.30	0.300	112.50
	67	5.40	0.415	110.50
	68	4.75	1.05	75.00
	69	4.70	0.515	56.00
	70	4.75	0.820	45.00
Velappaya	71	6.10	0.023	150.00
	72	6.15	0.021	145.00
	73	6.20	0.022	130.00
	74	6.20	0.030	82.50
	75	5.90	0.024	120.00
	76	5.80	0.011	67.50
	77	5.75	0.012	48.00
	78	6.30	0.012	37.50
	79	6.20	0.013	50.50
	80	5.50	0.014	45.00

Table 17. Soil reaction, electrical conductivity and phosphorus fixing capacity, mean and range values for surface samples

Soil seriesm	Soil reaction (1:2.5)	Constituents Electrical conductivity (1:2.0), mmhos/cm	Phosphorus fixing capacity, mg P/100 g soil
Thodupuzha	5.5-6.4 (5.85)	0.030-0.094 (0.057)	73.5-100.5 (87.60)
Mulamthuruthy	3.7-7.00 (5.33)	0.023-0.585 (0.211)	53.00-95.00 (67.25)
Kothamangalam	4.75-6.50 (5.74)	0.023-0.060 (0.040)	10.00-75.00 (44.7)
Punnamattom	5.30-7.00 (6.29)	0.035-0.330 (0.155)	67.00-150.00 (102.1)
Ikkanadu	5.5 -6.30 (5.91)	0.058-0.184 (0.099)	111.70-187.50 (142.55)
Ayyanthole	5.10-6.15 (5.60)	0.035-0.180 (0.075)	37.5 -90.00 (69.91)
Konchira	4.40-5.40 (4.73)	0.140-1.05 (0.40)	45.00-112.50 (82.2)
Velappaya	5.50-6.30 (6.04)	0.011-0.30 (0.018)	37.50-150.00 (87.6)

The electrical conductivity values varied from 0.011 mmhos/cm in Velappaya series (No.76) to 0.330 mmhos/cm in Punnamattom series (No.35) for dry lands, but for wet lands, it varied from 0.023 mmhos/cm in Mulamthuruthy and Kothamangalam series (No.16, 22 and 25) to 1.05 mmhos/cm in Konchira series (No.68).

The phosphorus fixing capacity of soils varied from 67.00 to 150.00 mg P/100 g for Punnamattom series, 37.50 - 150.00 mg P/100 g for Velappaya series and 73.5 - 100.5 mg P/100 g for Thodupuzha series in the case of dry lands but in the case of wet lands, it varied from 111.70 to 187.50 mg P/100 g, 45.00 to 112.50 mg P/100 g, 53.00s to 95.00 mg P/100 g, 37.50 to 90.00 mg P/100 g and 10.00 to 75.00 mg P/100 g for Ikkanadu, Konchira, Mulamthuruthy, Ayyanthole and Kothamangalam series respectively.

7.3. Available nutrient content of soils

The available nutrients, nitrogen, phosphorus and potassium contents for the surface samples are given in Table 18, mean and range values in Table 19.

The available nitrogen content varied from 98.00 to 147.00 ppm for Punnamattom series, followed by Thodupuzha and Velappaya series, recording 65.10 to 111.00 ppm and 60.00 to 74.00 ppm respectively in the case of dry lands, but in the case of wet lands, the values recorded 135.00 to 160.00 ppm, 135.00 to 152.00, 74.00 to 111.00 ppm, 74.00 to 100 ppm and 60.00 to 93.00 ppm for Konchira,

Table 18. Available nutrient content of soils (surface samples), ppm

Soil series	N	P	K
1	2	3	4
Thodupuzha			
1	98.00	11.50	60.00
2	100.00	11.25	61.00
3	83.00	9.25	55.00
4	111.00	8.75	40.00
5	74.00	8.25	25.00
6	100.00	4 25	25.00
7	74.00	5.00	15.00
8	93.00	3.25	10.00
9	83.00	8.00	15.00
10	65.10	8.00	17.50
Mulamthuruthy			
11	83.00	18.25	5.00
12	92.00	10.25	6.00
13	100.00	17.00	5.00
14	93.00	20.25	10.00
15	74.00	16.50	5.00
16	83.00	10.75	6.50
17	93.00	11.00	7.50
18	74.00	11.50	7.00
19	111.00	12.00	7.50
20	111.00	12.00	20.00
Kothamangalam			
21	74.00	5.75	10.50
22	83.00	9.00	11.00
23	100.00	16.50	12.50
24	93.00	4.25	10.00
25	74.00	4.75	8.00
26	83.00	6.00	7.50
27	74.00	6.50	16.50
28	93.00	7.25	20.00
29	83.00	12.00	15.00
30	74.00	4.25	10.00

Contd.

Table 18. Continued

1	2	3	4
Punnamattom			
31	144.00	12.00	160.00
32	147.00	3.50	160.00
33	100.00	1.00	65.00
34	98.00	5.75	45.00
35	112.00	1.00	50.00
36	125.00	23.00	43.00
37	130.00	3.00	75.00
38	135.00	4.00	100.00
39	140.00	6.00	45.00
40	137.00	5.00	43.00
Ikkanadu			
41	135.00	2.00	10.00
42	144.00	2.50	45.00
43	135.00	1.25	40.00
44	152.40	1.30	17.50
45	135.00	1.50	17.50
46	144.00	2.00	18.00
47	135.00	3.00	16.00
48	152.00	1.50	17.00
49	152.00	2.00	20.00
50	144.00	1.50	20.00
Ayyanthole			
51	83.00	3.25	5.00
52	83.00	4.75	7.50
53	93.00	4.00	8.00
54	83.00	8.50	10.00
55	83.00	8.00	9.00
56	93.00	9.25	7.50
57	83.00	7.00	5.00
58	68.00	9.00	6.00
59	60.00	30.00	9.00
60	75.00	2.00	10.00

Contd.

Table 18. Continued

1	2	3	4
Konchira			
61	135.00	4.25	12.50
62	152.00	4.50	15.00
63	144.00	3.00	20.00
64	160.00	2.50	18.00
65	152.00	4.00	20.00
66	135.00	5.25	13.00
67	160.00	3.50	10.00
68	135.00	4.75	25.00
69	152.00	5.50	15.00
70	144.00	4.00	16.00
Velappaya			
71	60.00	1.50	45.00
72	68.00	5.00	30.00
73	60.00	1.00	27.50
74	74.00	1.50	25.00
75	68.00	1.60	27.50
76	60.00	2.00	26.00
77	68.00	17.75	70.00
78	60.00	15.00	50.50
79	74.00	12.00	30.00
80	68.00	2.00	35.00

Table 19. Available nutrient content of soil, mean and range values for surface samples, ppm

Series name	N	P	K
Thodupuzha	65.10-111.00 (88.11)	3.25-11.50 (7.75)	10.00-61.00 (32.3)
Mulamthuruthy	74.00-111.00 (91.5)	10.25-20.25 (13.9)	5.00-20.00 (7.9)
Kothamangalam	74.00-100.00 (83.1)	4.25-16.5 (7.62)	7.50-20.00 (12.05)
Punnamattom	98.00-147.00 (126.8)	1.00-23.00 (6.42)	43.00-160.00 (72.6)
Ikkanadu	135.00-152.00 (142.8)	1.25-3.00 (1.85)	10.00-45.00 (22.1)
Ayyanthole	60.00-93.00 (80.04)	2.00-30.00 (8.67)	5.00-10.00 (7.7)
Konchira	135.00-160.00 (146.9)	2.50-5.50 (4.12)	10.00-25.00 (16.35)
Velappaya	60.00-74.00 (66.00)	1.00-17.75 (5.93)	25.00-70.00 (36.6)

Ikkanadu, Mulamthuruthy, Kothamangalam and Ayyanthole series respectively.

The available phosphorus content of the soils recorded 1.00 to 23.00 ppm, 1.00 to 17.75 ppm and 3.25 to 11.50 ppm for Punnamattom, Thodupuzha and Velappaya series respectively for dry lands, but for wet lands, it recorded 2.00 to 30.00 ppm, 10.25 to 20.25 ppm, 4.25 to 16.5 ppm, 2.50 to 5.50 ppm and 1.25 to 3.00 ppm for Ayyanthole, Mulamthuruthy, Kothamangalam, Konchira and Ikkanadu series respectively.

The available potassium content of the soils recorded 43.00 to 160.00 ppm, 25.00 to 70.00 ppm and 10.00 to 61.00 ppm for Punnamattom, Velappaya and Thodupuzha series respectively for dry lands, but for wet lands, it recorded 10.00 to 45.00 ppm, 10.00 to 25.00 ppm, 7.50 to 20.00 ppm, 5.00 to 20.00 ppm and 5.00 to 10.00 ppm for Ikkanadu, Konchira, Kothamangalam, Mulamthuruthy and Ayyanthole series respectively.

8. Soil classification

The classification of pedons under taxonomy upto the subgroup level have been attempted and presented in Table 20. Pedons I, IV and VIII represent the uplands, I and VIII have argillic horizon satisfies the percentage base saturation requirement hence classified under Ultisols. Profiles III and IV are classified under Entisol, while II, V, VI and VII are Inceptisol, derived from alluvium and colluvial

Table 20. Classification of soils according to soil taxonomy (1975)

Profile	Soil series	Location	Taxonomic name (sub group level)
I	Thodupuzha	Mothakulangara	Typic Kandiustults
II	Mulamthuruthy	Athany	Aquic Dystropepts
III	Kothamangalam	Angamaly	Typic Haplaquents
IV	Punnamattom	Chovvara	Typic Troporthents
V	Ikkanadu	Cherianadu	Aquic Dystropepts
VI	Ayyanthole	Potta	Aquic Dystropepts
VII	Konchira	Thrikkakara	Aquic Humitropepts
VIII	Velappaya	Pariyaram	Typic Kandiustults

sediments and subjected to periodical addition of sediments and hence are younger soils.

9. Fertility capability classification (F.C.C.)

The fertility capability classification of the soil series based on the characters of the surface soil 0-20 cm as outlined by Buol and Couto (1981) is described in Table 21. The fertility capability classes identified using standard notations and the major limitations and management considerations of the soil are described.

Table 21. Fertility capability classification (FCC) of soils

Serial No.	Soil series	FCC	Main limitation and management consideration
1	2	3	4
1	Thodupuzha	L", L", LR, e, h, i	Good water holding capacity, medium infiltration capacity, gravely loam over gravely loamy sub soil subjected to severe erosion hazard, low ability to retain nutrients and cations, heavy application of nutrients in splits, liming required for most crops, high P fixation capacity, requires high levels of P, sources and method of application to be carefully considered.
2	Mulamthuruthy	L", L", g, e, k, i	Good water holding capacity, medium infiltration gravely loam over gravely loamy sub soil, limitations in drainage which could affect some crops in low topographic position, where drainage is limited provision for drainage to be made, low ability to retain nutrients, K to be monitored and frequent split application, high P fixation, requires high levels of P, sources and method of application to be carefully considered.

Contd.

Table 21. Continued

1	2	3	4
3	Kothamangalam	L', L', g, e, k, i	Good water holding capacity, medium infiltration gravelly loam over gravelly loamy sub soil, limitations in drainage which could affect some crops in low topographic position, where drainage is limited, provision for drainage to be made, low ability to retain nutrients, K to be monitored and frequent split application, high P fixation, requires high levels of P, sources and method of application to be carefully considered.
4	Punnamattom	C, L, LR, e, h, k, i	Clayey top soil, loamy sub soil, low infiltration rates, potential high runoff if slopy, succeptible to severe erosion, priority to be given in erosion control, low ability to retain nutrients, liming based on wet pH, K to be monitored and frequent split application, high P fixation, requires high levels of P, sources and method of application to be carefully considered.

Contd.

Table 21. Continued

1	2	3	4
5	Ikkanadu	L, L', g, k, i	Good water holding capacity, loamy over gravelly loamy sub soil, limitations in drainage which could affect some crops in low topographic positions, where drainage is limiting, provision to be made for drainage, high P fixation capacity required high levels of P sources and method of application to be carefully considered.
6	Ayyanthole	L, c', g, e, i	Good water holding capacity, loamy over gravelly clay sub soils, low permeability rates due to clayey sub soil, limitation in drainage which could affect some crops in low topographic position, where drainage is limited, provision for drainage to be made, low ability to retain nutrients, high P fixation requries high levels of P, sources and method of application to be carefully considered.

Contd.

Table 21. Continued

1	2	3	4
7	Konchira	C", C", g, e, i	Low infiltration rates, gravelly clay over gravelly clayey sub soil, limitation in drainage which could affect some crops in low topographic position, where drainage is limited, provision for drainage to be made, liming based on wet pH, high P fixation, requires high level of P sources and method of application to be carefully considered.
8	Velappaya	L", L', LR, g, e, k, i	Good water holding capacity, gravelly loam over gravelly loamy sub soil, succeptible to severe soil deterioration from erosion exposing undesirable sub soil, high priority to be given to erosion control, limitation in drainage which could affect some crops in low topographic position, where drainage is limited provision for drainage to be made, low ability to retain nutrients, liming based on wet pH, K to be monitored and frequent split application, high P fixation, requires high levels of P sources and method of application to be carefully considered.

Discussion

DISCUSSION

The results of the study pertaining to profile morphology, physico-chemical properties, behaviour of iron fractions, available nutrients of surface samples and fertility capability classification are discussed.

1. Profile morphology

Out of eight soil series selected for study, three were located in the uplands consisting of well drained soils represented by Thodupuzha, Punnamattom and Velappaya series. The remaining five soils represented the major portion of the command area consisting of imperfectly drained paddy lands occupying the valley between the undulating laterite hills. The two groups of soils thus presented contrasting morphological features. The detailed morphological descriptions of profiles are shown in Appendix-I.

Colour is a predominant and observable morphological feature that is often taken as a diagnostic property of agricultural importance. The upland soils namely Thodupuzha, Punnamattom and Velappaya had predominant hue of 7.5 YR for the surface soils followed by hues of 5 YR in the sub surface horizon. Thodupuzha and Velappaya series represent the typical mid upland laterite soil while Punnamattom developed from alluvium deposited by rivers and stream along the banks. These soils are typical of the tropics and intensly weathered with haematite dominating the mineral assemmblage of the sand fraction. Haematite has strong pigmenting effect and results in colour ranging from yellow to red, with red colours often dominating the well drained areas (Schwertmann, 1971). These soils had a fairly high free iron oxide content 1.2 to 1.7 per cent, which has also contributed to colour. Richness in iron oxide especially free iron oxide coupled with well drained conditions both external and internal have been responsible for the reddish colour of these soils. The soils identified in the valleys had surface colours with brown hue (10 YR) dominating. The sub surface layers have predominating greyish colours with red and yellow mottles observed in Mulamthuruthy, Kothamangalam and Ayyanthole series. Organic matter addition during pudding is a common practice in paddy cultivation and has been responsible for the brownish colour of these soils. Aquic features like grey colours, mottles and characteristic greyish colours of sub surface layers are typical of soil with ill drained condition. The soil series namely, Mulamthuruthy, Kothamangalam, Ikkanadu, Ayyanthole and Konchira are all located in the valley bottoms which represent the lowest physiographic position in toposequence identified in laterite landscape in Kerala (Venugopal, 1980). The colour pattern observed in these soils are the result of the physiographic position and the consequent changes in water table and drainage conditions.

Weak to moderate subangular blocky structure was observed in the upland soils represnted by profiles I, IV and VIII. The structural development was more pronounced in the lower horizon. The high sesquioxide content of these soils and the conducive drainage conditions have been responsible for the good structural development observed in these soils (Jacob, 1987).

Wet land soils namely II, III, V, VI and VII series on the other hand, had weak subangular blocky surface structure, followed by massive structure in the sub surface layers. Puddling of these soils for paddy cultivation, the high water table and consequent poor drainage condition have been responsible for the weak structure and poor horizon development as observed in these soils (Martini and Mosquera, 1972) have observed similar features in soils of similar physiographic situation and has mainly attributed it to rejuvenation of landscape.

Coarse fragments formed a predominant part in all the horizon of the soil profiles especially Thodupuzha and Velappaya series representing the laterite soils of the upland. Jacob (1987) working on laterite soils of Kerala observed high content of coarse fragments which tended to increase with depth in soil profile. The ferruginous gravel according to Mohr and Van Baren (1959) is mainly the disintegration product of fossilized laterite. Similar soils have been described in South Asia (Panabokhe, 1967) and in the tropics at large (Thomas, 1974). The presence of such a large volume of coarse fragments in these soils cannot be disregarded since it affects soil properties like pore size distribution, penetrability to roots, water retention and transmission characterisitcs. Punnamattom series though located in upland has developed mainly from river alluvial sediments and hence has relatively lesser gravel. The wet land soils representing profiles II, III, V, VI and VII show wide range in gravel content. The soils of valley are formed mainly by deposition of materials by alluviation and surface wash from surrounding hills. The wide variations in gravel content are mainly due to site differences and slope which cause differential transport of materials by soil creep and surface wash from hills. The formation of deep soils with comparatively lower gravel content can be attributed to above process (Carson and Kirkby, 1978).

2. Physical properties

2.1. Mechanical composition of soils (Table 2 and 3)

Sand was dominant size fraction for all the soil series selected for the study. All the soils in the area are developed from acid igneous rock with quartz predominating the light mineral suite. The acid igneous rock on weathering produce quartz rich infertile soils. The higher sand fraction owes its origin to parent material from which the soils were formed.

Silt was the lowest among the size fractions. The intense weathering conditions of the profiles have been responsible for the complete transformation of the feldspar to clay with insignificant proportion of silt (Radwanski and Olier, 1959). The clay fraction showed migration to lower layers and is mainly the result of high rainfall condition (morethan 2500 mm) in the study area. Silt had a dominating effect in the textural class. Silt and silt loam surface texture with silty clay loam in the sub surface layers of profiles were the typical sequence of textural class observed.

Among the textural ratios, silt/clay ratio was taken as an index of weathering in soil. Van Wambeke (1967) has reported silt/clay ratio less than 0.15 and weatherable minerals less than 3 per cent as indicative of highly weathered condition. Judged from the above, all the soils registered values above the stipulated limit indicating the less mature nature of soils. The soils of the command area occupy lower slope positions namely the foot slope and valley which are subjected to rejuvenation of landscape by various slope processes thereby affecting the ageing processes (Martini and Mosquera, 1972). The silt/clay ratio of both the upland and wetland soils fall within the same range indicating similarities in their maturity.

2.2. Moisture retention characteristics (Table 4 and 6)

The moisture held at 1/3 bar varied from 13.1 to 30.4 per cent (profile mean) and closely followed the clay content. Positive relationship between clay content and 1/3 bar has been observed by Jacob (1987) in laterite soils of Kerala. The moisture held at 15 bars and available water capacity also showed similar trends closely following the distribution of clay. Another feature is the significantly larger proportion of coarse fragments observed in these soils which drastically affected the soil volume exposed to roots and hence its capacity to supply water. This highlights the need for taking into consideration the gravel content in addition to clay and organic matter in deciding the available water capacity of soils. Thulaseedharan (1983) has made similar observation and has developed prediction equation to arrive at available water capacity taking into account gravel, organic matter and texture of soils. It is significant to note that the retention of 15 bar moisture per unit weight of clay is more or less same for all the soils indicating the more or less similar nature of the clay minerals namely Kaolinite, Punnamattom and Ikkanadu series recorded slightly high values for available water, the parent material of these soils is dominantly river alluvium, the presence of micaceous and other expanding clay minerals had partly contributed to the higher available water content of these soils.

2.3. Physical constants

The apparent density did not reveal appreciable differences within soil profiles and also between soils from different locations. The mean values for the profiles varied from 1.06 to 1.57. The organic matter content of all the soils being low it's influence especially in the surface horizon is not much in evidence. In Konchira soils, however the last horizon (No.32) with the highest organic matter content showed the lowest value for bulk density. The dominating effect of coarse fragments on the bulk density has been reported by Ushakumari (1983) on laterite soils of Kerala. The mean value of profiles for the coarse fragments (Table 3) indicate the dominating effect of gravel on this property. Punnamattom and Ikkanadu series with low gravel content revealed low values for apparent density. In respect of Konchira series a fairly high organic matter fraction had a depressing effect on the apparent density values.

The absolute specific gravity did not show appreciable differences within the profile and also between soil series. The profile mean varied from 2.17 to 2.44. The narrow range in the property is indicative of the more or less similar primary mineral assemblage of these soils (Elsy, 1989). The low specific gravity values of Konchira series is evidently due to high organic matter content.

Porosity was calculated from particle density and bulk density and therefore factors which influence these parameters affect the porosity too. The mean values of the profiles for the soils varied from 42.2% to 60.6%. Wilde <u>et</u> <u>al</u>. (1972) had observed that a reasonable pore volume of soils varied from 30 to 70%. Judged from these, all the soils under study fall within this range and have little resistance to root penetration and also water intake rates. This agrees with the observation of Ushakumari (1983) for upland laterites of Kerala.

The maximum water holding capacity and volume expansion were closely related to nature and content of organic matter. The data revealed erratic profile trends. The predominant clay minerals in all soils under investigation were an admixture of Kaolinite and hydrous oxides which have a low capacity to hold water and are non expansive. Differences in clay content between horizon did not apparantly affect these properties. In respect of Punnamattom and Ikkanadu series the parent material being rive alluvium the presence of micaceous and expansive mineral, might have contributed to slightly higher values observed in these soils. The influence of organic matter on these properties is clearly evident in Konchira series which recorded highest value for water holding capacity and volume expansion.

3. Chemical characteristics

3.1. pH, electrical conductivity and organic carbon (Table 7 and 8)

The soils, were all acidic in reaction as is expected of highly leached tropical soils (Vine, 1956). The acid nature of parent rock, intense weathering conditions and leaching of bases under high rainfall are factors contributing to acidity. The extremely low pH of 3 observed in Konchira series is due to organic debris observed in this layer.

The electrical conductivity values recorded were very low and showed little variation within the profile and between soils from different locations.

The exchange acidity values (profile mean) did not reveal appreciable difference within profiles and also between soils from different locations. The higher values observed in Konchira series is attributed to organic debris noticed in this layer.

The organic carbon content of soils were low as is characteristic of tropical soil. The profile means indicate variation of 0.38 to 2.55%. A steady decrease in organic carbon content with depth was a feature observed in all soils except for Konchira, where the last layer showed accumulation of organic matter which is mainly geogenic in origin. Organic matter mineralisation under tropical condition according to Sanchez (1976) was very rapid causing its depletion.

3.2. Total nutrient content (Table 9 and 10)

The nitrogen content (profile means) varied from 0.06 to 0.16%. The surface horizon invariably showed high content with steady decrease with depth. This closely followed organic carbon distribution.

The total reserves of P_2O_5, K_2O, CaO, MgO and Na_2O were low as is expected of humid tropical soil, where intense weathering conditions leave very little of primary minerals, except quartz. The soils of the command area were developed from acid crystalline rock which are again poor in bases. Thus the low nutrient content observed in these soils is a reflection of parent geology as is revealed from the result of present investigation. Huges (1981) observed that the total reserves of plant nutrient is mainly a function of minerology of sand fraction.

Fe_2O_3 content was fairly high with higher content observed in upland laterite soils I and VIII., Profile trends were erratic except for Ikkanadu series where steady increase with depth was observed. The soils of the State are rich in haematite Kaolinite and hydrous oxides and accounts for high sesquioxide content. The Fe_2O_3 is retained both by the sand and the clay fraction, Jacob (1987). This accounts for the high content of Fe_2O_3 in these soils.

3.3. Cation exchange capacity properties (Table 10 and 11)

The NH_4OAc CEC was low and profile means varied from 2.80 to 12.82 me/100 g. Profile trends were erratic except for Ikkanadu series which showed a decreasing pattern with depth, while reverse was true for Konchira series. The fact that low activity clays dominated the minerology of clay fraction of the soils from different locations was clearly brought about by the narrow range observed in CEC values. Differences in clay content between soil has not reflected in CEC values highlighting the importance of nature of clay fraction. Coleman and Thomas (1967) have observed that soils rich in low activity clays like Kaolinite, Halloysite and hydrated oxides of Fe and Al have low CEC lending further support to the observations made in the present investigation.

3.4. Exchangeable bases and percentage base saturation

Ca and Mg were the predominant cation in the exchangeable complex. The mean value for the profiles showed the exchangeable bases were in the order Ca $>$ Mg $>$ K $>$ Na for Thodupuzha, Punnamattom, Ikkanadu, Ayyanthole and Velappaya, while for Mulamthuruthy, Kothamangalam and Konchira the exchangeable sodium was slightly on higher side as compared to exchangeable potassium. Jacob (1987) working on laterite soils of Kerala reported low values for exchangeable bases. The percentage base saturation varied from 15.66 to 74.68 and it followed the exchangeable calcium distribution. The soils being mainly acidic, the percentage base saturation values as expected were low except for Mulamthuruthy series. This is typical of soils of heavy rainfall regions.

3.5. Extractable iron and active iron ratio (Table 13 and 14)

The dithionite extractable iron (Fe_d) gives a reasonable estimate of the free iron oxides, while those extracted by NH_4OAc (Fe_o) represents the more or less amorphous (Mehra and Jackson, 1960 and Mc Keague and Day, 1966). The Fe_d formed the major portion of total iron in all the soils under investigation. The profile means varied from 0.67 to 1.71. The accumulation of Fe_d in sub surface layer was observed in all the soils except Kothamangalam and Punnamattom. The accumulation in sub surface layers is suggestive of passive movement of these oxides along with the finer fractions (Blume and Schwertmann, 1969).

The Fe_d expressed as percentage of total iron referred to as degree of freeness of iron is often taken as an indicator of age of soils (Alexander, 1974). The profile mean showed not much variation indicating the more or less same rating of the soils in the maturity scale.

The Fe_o recorded low values and not much variation was observed between soils, however, slightly higher values were observed for Konchira series. The higher organic matter content of soils might have been responsible for the enrichment of amorphous oxides indicating the inhibitory effect of organic matter in the crystallisation of iron oxides (Jacob, 1987). Low values for Fe_o for soils developed from acidic rocks have been reported by Juo et al. (1974).

Consistent with low values of Fe_o the active iron ratio also registered low values. Alexander (1974) has reported strikingly low values approaching zero in all tropical soils. The profile means observed a range of 0.12 to 0.44. The narrow range in this ratio is further indicative of more or less same rating in maturity scale.

4. Analysis of surface samples

Out of eight soil series selected from command area except for profiles I, IV and VIII all others are paddy lands. Analysis of surface samples 0-20 cms was also undertaken to get an insight into the fertility characteristics of soil samples collected from widely sapced areas.

The textural class of soils showed that silty textures were predominant in all soils. The command area include regions below 50 feet contour and most of the soils collected were paddy land or areas which were influenced by deposition of alluvium from river. This is probably responsible for silty structures predominating surface soils. As discussed earlier the soils were acidic, the pH value determined are for dry soils. In case of paddy soils, it would be worth while arriving at lime recommendations based on pH of water logged soils. Nair (1977) reported a negative correlation between pH on water logging and lime requirement and suggested this as a useful index for lime recommendation. This is expecially true for paddy soils selected in this study and would considerably reduce the lime required for neutralising acidity. The P fixing capacity of soils are high, based on this property, soils of command area fall in following order Ikkanadu > Punnamattom > Velappaya > Thodupuzha > Konchira > Ayyanthole > Mulamthuruthy > Kothamangalam. High P fixing capacity for Kerala soils have been reported by Nair and Padmaja (1983) and this has been attributed to high sesquioxide content and the finer fractions. The high P fixing capacity of soil, highlights the need for high levels of P fertilisation, appropriate sources of P and fertiliser application methods to meet crops requirement.

4.1. Available nitrogen, phosphorus and potassium

The status of available nitrogen of surface soils was very low for Thodupuzha, Mulamthuruthy, Kothamangalam, Ayyanthole and

Velappaya, low to medium for Punnamattom, medium to high for Ikkanadu and Konchira. Available phosphorus was low to medium for Thodupuzha, Kothamangalam, Punnamattom, Ayyanthole and Velappaya, medium for Mulamthuruthy and low for Ikkanadu and Konchira. In respect of available potassium, all the soils had low rating except for Punnamattom where it was low to medium. The low organic matter content and cation exchange capacity are the factors which have contributed to the low available nutrient content of the soil. Nair (1973) obtained low values for nitrogen, phosphorus and potassium and attributed this to the low organic matter and CEC. The above observations regarding the status of major nutrients outlines the need for detailed studies on soil test crop response to arrive at need based fertiliser recommendation for crops. This aspect assumes importance in the present day context of high ccost of fertiliser inputs.

5. Fertility capability classification (Fcc)

The microheterogenity of soils of tropics is a reality and this prompt Buol and Couto (1981) to make use of the Fcc for tropical soil. Attempts have been made by Sanchez and Buol (1975) to apply this concept on soils of aquic moisture regime. The Fcc was therefore designed to group soils that have same trend of limitation from the point of view of fertility management focussing on the upper 20 cms of the soil (Buol, 1972).

Fcc of the soils of the command area have been attempted with a view to highlight the major limitation and management requirement of the various soils. From the classification it is observed that the dry land soils namely Thodupuzha and Velappaya have gravely loam top soil over gravely loamy sub soils succeptible to severe erosion. In respect of Punnamattom series though they are gravel free, risk to soil erosion is high. Soil erosion control, needs priority in these areas. The gravely nature of soils also outlines the need in calculating water requirement of crops taking into account this fraction.

With regard to soils with aquic moisture regimes, high P fixing capacity was a common feature. Low K reserves and low nutrients holding capacity was observed in Mulamthuruthy, Kothamangalam and Ikkanadu series while adequate K reserves were noted in Ayyanthole and Konchira, here again quantity of fertilizer to be applied, sources and method of application are to be decided based on site specific characteristics.

The command area of Edamalayar irrigation project covers wet lands and also garden lands occupying the foot slopes. Paddy is the major crop grown in this area in rotation with pulses, vegetables and banana depending on local site situations. The uplands are utilized for perennials and other intercrops in areas with assured irrigation.

The present study points to the very significant changes that could be made in the soil surveys now being undertaken in command areas. The present surveys mainly aime at classification of soils from the pedologists point of view on the basis of properties of the soil pedon. Soper and Mc Cracken (1973) have observed that in U.S.A. as much as 70 per cent of crop yields can be attributed to top soil properties. This aspect is equally true for tropics. Inclusion of the fertility parameters of surface soils for already defined soil units will enhance the utility value of soil survey report especially those carried out in the command area of irrigation project. The resulting soil maps with Fcc super imposed will help to identify groups and areas with similar limiations and management requirements. Soil fertility experiments in such identified soil units will aid in better interpretation and extrapolation of results. Such detailed studies on soils using these maps will provide a fund of information on soil fertility aspects which could be utilized for better management and sustained use of these soils for profitable crop production.

Summary

SUMMARY

In the present investigation attempt has been made to evaluate the morphological, physical and chemical characteristics of eight soil series occupying in command area of Edamalayar irrigation project. Out of these eight soil series selected for study, three were located in uplands consisting of well drained soils represented by Thodupuzha, Punnamattom and Velappaya series. The remaining five soils characterised by imperfectly drained paddy lands, occupy the valley between the undulating laterite hills namely, Mulamthuruthy, Kothamangalam, Ikkanadu, Ayyanthole and Konchira. Profile pits were dug at these different locations and examined for their morphological features. Soil samples representing the different horizons were collected for laboratory studies. The physico-chemical characteristics of the soil profiles were investigated with a view to study the interrelationship between the various properties and to relate these characteristics to the genesis of these soils. Surface samples collected from different locations under each series were also analysed for available nutrients and other fertility parameters to arrive at fertility capability classifications.

1. The soils of the uplands namely profiles I, IV and VII had predominantly red hues while soils from valleys had predominantly brown surface soils followed by subsurface layers with greyish colour and mottling.

2. Good structural development was noticed in upland soils but wet lands had weak subangular blocky surface structures followed by massive structure in the sub soils. Poor structural development and weak horizon development were features characteristic of the imperfectly drained wet lands.

3. Coarse fragments formed a predominant part in the soils from upland. Increase in content with depth was a feature noticed. In respect of the soils of the wet lands, wide variation in its content was observed.

4. Sand formed the predominent size fraction for all the soils from both uplands and wet lands. Very low content of silt with clay illuviation to lower layers were features common to all the soils.

5. The silt/clay ratio of all the soils under study fall within the same range indicating the less mature nature of soils.

6. Punnamattom series coming under upland soils and the imperfectly drained Ikkanadu series coming under wet land soils recorded slightly higher available water content.

7. The apparent density and absolute specific gravity did not reveal appreciable differences between soils from various locations. Konchira, Ikkanadu and Punnamattom recorded slightly low values for absolute specific gravity, while Konchira recorded low values for both these properties. In respect of water holding capacity

and volume expansion, high values were observed in Ikkanadu, Punnamattom, Konchira series with Konchira recorded the highest value.

8. In general all the soils were acidic in reaction with extremely low pH observed for Konchira series.

9. Organic carbon content of all soils from both upland and wet land soils were low. A steady decrease in organic carbon content with depth was observed in all soils except for Konchira, where the last layer showed accumulation of organic matter.

10. The nitrogen content of all soils were high in the surface layers. Steady decrease with depth was observed except for Konchira series.

11. The total reserves of P_2O_5, K_2O, CaO, MgO and Na_2O were low and is mainly a reflection of the minerology of the sand fraction which was dominated by quartz.

12. Fe_2O_3 content was fairly high in the case of upland profile I, IV and VIII as compared to wet lands. Profile trends were erratic except for Ikkanadu series where steady increase with depth was noticed.

13. The cation exchange capacity calculated by NH_4OAc method was low for all soils. Profile trends were irratic except for Ikkanadu series which showed a decreasing trend with depth. Among the

exchangeable bases, Ca and Mg formed the predominant cations. The exchangeable bases of the soils were in the order Ca > Mg > K > Na for Thodupuzha, Punnamattom, Ikkanadu, Ayyanthole and Velappaya, while for Mulamthuruthy, Punnamattom and Konchira the exchangeable sodium was slightly higher than potassium.

14. The percentage base saturation values for all the soils were low except for Mulamthuruthy series and it followed exchangeable calcium distribution.

15. The Fe_d (dithionite fraction of iron) formed the predominent iron fraction. Based on "degree of freeness of iron" all the soils indicated the more or less same rating in the maturity scale.

16. The Fe_o (oxalate extractable iron) and active iron oxide ratio (Fe_o/Fe_d) recorded low values for all the soil series.

17. The P fixing capacity of all the soils were high and it followed the order Ikkannadu > Punnamattom > Velappaya > Thodupuzha > Konchira > Ayyanthole > Mulamthuruthy > Kothamangalam.

18. Pedons I and VIII are classified under ultisols, III and IV, entisols while II, V, VI and VII are inceptisols. Classification upto the sub group level have been attempted.

19. Among the available nutrients of surface soils, the nitrogen was very low to low for Thodupuzha, Mulamthuruthy, Kothamangalam, Ayyanthole and Velappaya, low to medium for Punnamattom, medium

to high for Ikkanadu and Konchira. Phosphorus was low to medium for Thodupuzha, Kothamangalam, Punnamattom, Ayyanthole and Velappaya, medium for Mulamthuruthy and low for Ikkanadu and Konchira. In the case of available Potassium, all the soils had low rating except for Punnamattom where it was low to medium.

20. From the classification it is observed that the dry land soils namely Thodupuzha and Velappaya have gravely loam top soil over gravely loamy sub soils succeptible to severe erosion. In respect of Punnamattom series though they are gravel free, risk to soil erosion is high. Soil erosion control needs priority in these areas. The gravely nature of soils also outlines the need in calculating the water requirement of crops taking into account this fraction. With regard to soils with aquic moisture regimes, high P fixing capacity was a common feature. Low K reserves and low nutrient holding capacity was observed in Mulamthuruthy, Kothamangalam and Ikkanadu series while adequate K reserves were noted in Ayyanthole and Konchira, here again quantity of fertilizer to be added, sources and method of application are to be decided based on site specific characteristics.

References

REFERENCES

Acharya, N., Sahu, S.K. and Misra, B. 1979. Studies on distribution of iron in paddy soils of I.A.D.P. district of Sambalpur. Indian J. agric. Chem. 12(1):53-60.

*Ahn, P.M. 1970. West African Soils. 3rd ed., Oxford University Press, London. pp.332.

Aiyer, R.S., Rajagopal, C.K. and Money, M.S. 1975. Available Zn, Cu, Fe and Mn status of the acid rice soils of Kuttanad, Kerala State. Agric. Res. J. Kerala. 12(1):15-19.

Alexander, E.B. 1974. Extractable iron in relation to soil age on terrace along the Truckee river, Nevada. Proc. Soil Sci. Soc. Am. 38:121-124.

Amma, S.S. and Aiyer, R.S. 1973. Potassium status of the acid rice soils of Kerala State. Agric. Res. J. Kerala.

Arduino, A.R., Banbenis, E., Carrano, F. and Forno, M.G. 1984. Estimating relative ages from iron oxide/total iron oxide ratios of soils in the Western P. Valley, Italy. Geoderma. 33:39-52.

Arduino, A.R., Banberis, E., Manson, F.A.J., Zainini, E. and Franchini, M. 1986. Iron oxides and clay minerals within profiles as indicator of soil age in Northern Italy. Geoderma. 37:45-55.

Aubert, G. 1962. Observations on pedologic factors that may limit the productivity of soils of the humid tropics. Trans. Comm. IV and V Int. Soc. Soil Sci. Palmerston North, N.Z.1, 552-565.

Bastin, B. 1985. Physico-chemical characterisation of red soils in different regions of Kerala. M.Sc.(Ag.) thesis, Kerala Agricultural University, Trichur.

Bhattacharya, T., Ghosh, K.S. and Prakash, N. 1983. Chemical and morphological characteristics of amorphous materials present in red soils derived from granite-gneis. Clay. Res. 2(1):20-27.

Blume, H.P. and Schlichting, E. 1985. Morphology of wet land soils. In Wetland soils, characterisation, classification and utilization. Proceedings of a Workshop held 26 March to 5 April 1984 under the joint sponsorship of The International Rice Research Institute.

Blume, H.P. and Schwertmann, U. 1969. Genetic evaluation of profile distribution of Al, Fe and Mn oxides. Proc. Soil Sci. Soc. Am. 33:438-444.

*Brammer, H. 1962. Ghana soils. Wills, J.B. (ed). Agriculture and Land use in Ghana. Oxford University Press, London. pp.88-126.

Buol, S.W. 1972. Soil fertility - capability assessment for use in the humid tropics. In. Characterisation of soils in relation to their classification and management for crop production (Ed) Greenland, D.J., Clarendon Press, Oxford, 30-50.

Buol, S.W. and Couto, W. 1981. Soil fertility-capability assessment for use in the humid tropics. In. Characterisation of soils in relation to their classication and management for crop production (Ed) Greeland, D.J., Clarendon Press, Oxford, 254-260.

Carson, M.A. and Kirkby, M.J. 1978. Hill slope form and Process. Cambridge University Press.

Chaudhury, T.N. and Ghildyal. 1969. Aggregate stability of puddled soil during rice growth. J. Indian Soc. Soil Sci. 17(3): 261-265.

Coleman, N.T. and Thomas, G.W. 1967. The chemistry of soil acidity. In. Soil acidity and liming, Agronomy No.12, American Society of Agronomy, Madison, p.1-41.

De Datta, S.K. 1981. Principles and practices of rice production. In. Wetland soils, characterisation, classification and utilization - Proceedings of a Workshop held 26 March to 5 April 1984 under the joint sponsorship of the International Rice Research Institute.

Dev, G. and Sharma, H.C. 1971. Effect of continuous submergence on soil reaction, electrical conductivity and oxidisable matter. J. Indian. Soc. Soil Sci. 19(4):369-373.

Dongale, J.H., Patil, E.P., Kanvilkar, S.A. and Chavan, A.S. 1987. Physico-chemical characteristics of lateritic soils in relation to their irrigability classification. J. Maharashtra agric. Univ.

Elsy, P.A. 1989. Physico-chemical characteristics, genesis and classification of soils from forest ecosystems in Kerala. M.Sc.(Ag.) thesis, Kerala Agricultural University, Trichur.

Ge, O.Z. and Su, G.O. 1986. Potassium supplying ability of paddy soil in Dongting lake plain. J. Soil Sci. China. 17(1):8-12.

Ghosh, S.K., Das, D.K. and Deb, D.L. 1973. Physical, chemical and minerological characterisation of Kari soils from Kerala. Paper presented in the symposium of acid sulphate and other acid soils of India held at Trivandrum in February, 1973.

Grant, C.J. 1964. Soil characteristics associated with the wet cultivation of Rice, in 'The Mineral Nutrition of the Rice Plant'. John Hopkins Press, Baltimore, Maryland.

Greenland, D.J. 1981. Soils and crop production in the low land humid tropics. In. Characterisation of soils in relation to their classification and management for crop production. (Ed) Greeland, D.J., Clarendon Press, Oxford, 1-9.

Gupta, V.K., Raji, H. and Singh, K. 1980. Distribution and relationship of micronutrients with soil properties of soils of South Western Haryana. Haryana agric. Univ. J. Res. 10(2): 235-241.

Halim, E.L., Damathy, A., Matwalli, Y. and Ibrahim, A.H. 1963. Potassium status in the soil of U.A.R. J. Soil Sci. Un. Arab. Repub. 3:143-174.

Hassan, M.A. 1977. Fertility investigation on the laterite soils of Kerala State. M.Sc.(Ag.) thesis, Kerala Agricultural University, Trichur.

Hazra, G.C. and Mandal, B. 1988. Distribution of DTPA extractable Fe, Mn, Cu and Zn in some acid alluvial soils of West Bengal and their effect of their submergence on their contents. Indian Soc. Soil Sci. **36**(1):169-172.

Hesse, P.R. 1971. A Text book of soil chemical analysis. John Murray Publishers Ltd., London, pp.520.

Hughes, J.C. 1981. Minerology. In: Characterisation of soils in relation to their classification and management for crop production (Ed.) Greeland, D.J., Clarendon Press, Oxford, p.30-50.

Iyer, M.S. 1979. Studies on laterite and red soil association in certain locations in Kerala. M.Sc.(Ag.) thesis, Kerala Agricultural University, Trichur.

Jacob, S. 1987. Characterisation of laterite soil from different parent materials in Kerala. M.Sc.(Ag.) thesis, Kerala Agricultural University, Trichur.

Jackson, M.L. 1958. Soil chemical analysis. Prentice Hall Inc., U.S.A., pp.498.

Jeffery, J.W.O. 1961. Defining the state of reduction of a paddy soil. J. Soil. Sci. **12**:172-179.

Juo, A.S.R., Moormann, F.R. and Maduakor, H.O. 1974. Forms and distribution of extractable iron and aluminium on selected soils of Nigeria. Geoderma **11**:167-179.

Kellog, C.S. 1949. Preliminary suggestions for classification and nomenclature of great soil groups in tropical and equational regions. Commow. Bur. Soil Sci. Tech. Comm. **46**:76-85.

Khan, S.K. and Mandal, L.N. 1973. Distribution of different inorganic forms of phosphorus in rice soils of West Bengal. J. Indian Soc. Soil Sci. **21**(4):395-402.

Koshy, M.M. 1970. The chemical nature of organic complexes in Kerala soils. Curr. Sci. **39**:353-354.

Koshy, M.M. and Brito-Mutunayagam, A.P.A. 1965. The mechanism of phosphate fixation in soils and the nature of retained phosphate. Agric. Res. J. Kerala. **3**(1):32-39.

Koshy, M.M. and Varghese, T. 1971. Soils of Kerala. Fert. News. **16**(11):51-57.

Kothandaraman, G.V. and Krishnamoorthy, K.K. 1978. Phosphorus fixation capacity of Tamil Nadu Soils. Madras agric. J. **65**(1):645-649.

Kuo, S. and Mikkelsen, D.S. 1979. Distribution of iron and phosphorus in flooded and unflooded soil profiles and their relation to phosphorus adsorption. Soil Sci. **127**(1):18-25.

Kurup, T.K.B. and Aiyer, R.S. 1973. Seasonal variations in soil reaction and soluble salt content of Kuttanad rice soils, Kerala State. Agric. Res. J. Kerala.

Kyuma, K. 1985. Fundamental characteristics of wetland soils. In. Wetland soils, characterisation, classification and utilisation. Proceedings of a Workshop held 26 March to 5 April 1984 under the joint sponsorship of The International Rice Research Institute.

Lissonite, L.E. 1960. The red earths and colloids of red earths. J. Soil Sci. **11**:77-81.

Lotse, E.G., Datta, N.P., Tomar, K.P. and Motsara, M.R. 1974. Minerological composition of some red and black soils of India. Proc. Indian nat. Sci. Acad. (40 B) **2**:216-226.

Luzio, W. 1985. Wetland soils of Chile. In. Wetland soils, characterisation, classification and utilization - Proceedings of a Workshop held 26 March to 5 April 1984 under the joint sponsorship of The International Rice Research Institute.

Maignien, R. 1960. Review of Research on Laterites. Nat. Resoun. Res. IV. UNESCO, Paris: 148.

Martini, J.A. and Mosquera, L. 1972. Properties of five tropepts in a toposequence of humid tropics in Costa Rica. Soil Sci. Soc. Am. Proc. **36**:473-477.

Mathew, R. and Nair, R.V. 1985. Moisture retention characteristics of red and forest soils of Kerala. Agric. Res. J. Kerala. **23**(1):17-23.

Mc Keague, J.A. and Day, J.H. 1966. Dithionite and Oxalate extractable Fe and Al as aids in differentiating various classes of soils. Can. J. Soil Sci. **45**:49-62.

Mehra, O.P. and Jackson, M.L. 1960. Iron oxide removal from soils and clays by a dithionite-citrate system with sodium bicarbonate. Clays Clat minerals, **7**:317-327.

Menon, P.K.G. 1975. Morphological and physico-chemical properties of the Kayal soils of Kuttanad, Kerala State. M.Sc.(Ag.) thesis, Kerala Agricultural University, Trichur.

Mohanty, S.K. and Filipovski, G. 1981. Characteristics and Fertility potential classification of rice soils of Yugoslavia. J. Indian Soc. Soil Sci. 29(2):233-240.

Mohanty, S.K. and Filipovski, G. 1982. Fertility potential classification of rice growing soils using principal component analysis. J. Indian Soc. Soil Sci. 30(3):

Mohr, E.C.J. and Van Baren, F.A. 1959. Tropical Soils. Interscience Publishers. Inc. New York.

More, D.S., Kadrekar, S.B. and Dongale, J.H. 1981. Effect of submergence on availability of iron and manganese in rice soils of Konkan. J. Maharashtra agric. J. 6(3):245-246.

More, D.S., Kadrekar, S.B. and Dongale, J.H. 1982. Effect of submergence on the electrochemical and chemical properties of rice soils of Konkan. J. Maharashtra agric. Univ. 7(2):122-125.

Nad, B.K., Goswami, N.N. and Leelavathi, C.R. 1975. Some factors influencing the phosphorus fixing capacity of Indian soils. J. Indian Soc. Soil Sci. 23(3):319-327.

Nair, C.K.N. 1945. Studies on the Kari soils of Travancore. M.Sc. thesis, University of Travancore.

Nair, B. 1970. Studies on copper and zinc status of Kerala rice soils and response to these elements by IR-8. M.Sc.(Ag.) thesis, Kerala Agricultural University.

Nair, K.H. 1973. Studies on the fertility status of the red soils of Kerala and the effect of adding nitrogen in combination with MNO_2 on the growth, yield and composition of rice. M.Sc.(Ag.) thesis, Kerala Agricultural University.

Nair, P.S. 1977. Studies on rice growing soils of Wyanad. M.Sc.(Ag.) thesis, Kerala Agricultural University.

Nair, K.M. and Padmaja, P. 1983. Phosphorus fixing capacity of major rice soils of Kerala. Agric. Res. J. Kerala **21**(1): 63-65.

Nikolayeva, S.A., Deryuzhinskaya, V.D. and Durishova, A.V. 1987. Forms of iron in paddy soils. Soviet Soil Sci. **19**(5):11-17.

Panabokke, C.R. 1967. Physical properties. In. Characterisation of soils in relation to their classification and management for crop production. (Ed.) Greenland, D.J., Clarendon Press, Oxford, 135-148.

Parvathappa, H.C. 1964. Study of characteristics and productivity of red soils of Mysore State. M.Sc.(Ag.) thesis, Madras University.

Patel, G.R. and Dangarwala, R.T. 1984. Availability of Fe, Mn and Zn in paddy soils of South Gujarath. GAU Res. J. **9**(2): 29-35.

Pillai, V.S. and Subramoney, N. 1967. Physico-chemical and micro-biological studies on the kari soils of Kerala. Agric. Res. J. Kerala 5(1):54-59.

Piper, C.S. 1942. Soil and plant analysis. Asian reprint, 1966. Hans Publishers, Bombay, pp.368.

Pisharody, P.N. 1965. Forms and distribution of iron manganese in rice soils of Kerala. M.Sc.(Ag.) thesis, Kerala Agricultural University.

Prameela, K.P. and Nair, R.V. 1985. Moisture retention characteristics of alluvial soils of Kerala. Agric. Res. J. Kerala. **23**(1):24-30.

Praseedom, R.K. 1970. Distribution of copper and zinc in soils of Kerala. M.Sc.(Ag.) thesis, Kerala Agricultural University.

Radwanski, S.A. and Olier, C.D. 1959. A study of an East African Catena. J. Soil Sci. **10:**149-168.

Raguraj, R. 1981. Studies on the physico-chemical properties of major soil series of Madurai district. M.Sc.(Ag.) thesis, Tamil Nadu Agricultural University.

Rajagopalan, V. 1969. Distribution of manganese and molybdenum in soils of Kerala and the effect of molybdenum on the growth of cowpea. M.Sc.(Ag.) thesis, Kerala Agricultural University.

Rajamannar, A., Ramaswamy, P.P. and Kirshnamoorthy, K.K. 1979. Organic matter level and some related characteristics of lateritic soils of different altitude under plantation. J. Indian Soc. Soil Sci. **27**(4):399-401.

Ramanathan, K.M. and Krishnamoorthy, K.K. 1973. Potassium availability in relation to growth of rice in different soils. J. Indian Soc. Soil Sci. **21**(2):181-186.

Ram, P. and Singh, B. 1975. Potassium in paddy soils of Eastern Uttarpradesh. J. Indian Soc. Soil Sci. **23**(2):222-226.

Rao, S.R. and Narasimham, R.L. 1986. Effect of flooding on CEC, AEC and exchangeable cations of some rice growing alluvial soils of coastal A.P. J. Res. APAU.

Raychaudhury, S.P. and Anantharaman, P.V. 1960. Characteristics of some Indian acid soils. J. Indian Soc. Soil Sci. **8**: 223-228.

Raychaudhury, S.P. and Reddy, P.S.A. 1963. Rating of some red soils of Bangalore district, Mysore State. J. Indian Soc. Soil Sci. **11**(3):311-319.

Reaves, G.A. and Berrow, M.L. 1984. Total copper content of Scottish soils. J. Soil Sci. **35**(4):583-592.

Richards, L.A. 1954. Diagnosis and Improvement of Saline and Alkaline Soils. U.S.D.A. Agri. Hand book No.60.

Sahu, S.K. and Acharya, N. 1976. A note on changes of soil reaction and specific conductance of some submerged rice soils of IADP District of Sambalpur. Indian J. agric. Chem. **9**(2):217-219.

Sankaram, A. 1966. A Laboratory manual for Agricultural Chemistry. Asia Publishing House