FERTILITY INVESTIGATIONS ON THE SOILS OF SOUTH KERALA IN RELATION TO THEIR PHYSIOGRAPHIC POSITIONS

BY

G. WILFRED GODWIN

THESIS

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DECLARATION

I hereby declare that this thesis entitled "Fertility investigations on the soils of South Kerala in relation to their physiographic positions" 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.

(G. WILFRED GODWIN)

Vellayani,
2-4-1987

CERTIFICATE

Certified that this thesis entitled "Fertility investigations on the soils of South Kerala in relation to their physiographic positions" is a record of research work done independently by Sri. G. Wilfred Godwin 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.

Alice Abraham

(ALICE ABRAHAM)
Chairman,
Advisory Committee,
Professor of Soil Science
and Agricultural Chemistry.

Vellayani,
2-4-87.

APPROVED BY:

Chairman

Dr. Alice Abraham

Members

1. Sri. P.A. Korah

2. Sri. P.R. Ramasubramonian

3. Dr. G. Raghavan Pillai

External Examiner

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G. WILFRED GODWIN

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INTRODUCTION

INTRODUCTION

The spatial variability of field soils is an important property to be accounted for in the management and utility of soils for various agricultural and non-agricultural functions.

The variability of soil properties even within narrowly defined mapping units is not appreciated or understood by the majority of persons who use the soil data for various purposes. This aspect of the study of soil has become the concern and interest primarily of those responsible for describing, classifying and mapping soils. Beckett and Webster (1971), Burgess and Webster (1980), Malik et al (1983), Raman et al (1983) and Dahiya et al (1984) have been largely responsible for advanced studies in this direction.

Variations in soil properties from point to point in the landscape brought out due to pedoturbations introduce a gradient which super imposes the variations introduced by other natural processes. The pattern of changes will be further complicated when it is associated with the loss, retention or burial of land surfaces due to erosion of soils located on a slopy terrain.

Within the soil itself, the physical and chemical processes tend to increase the lateral and vertical variability of properties. The plant nutrients which may be present in the organic or inorganic form differ in their degree of persistence and mobility leading to differences in resident time.

Spatial variability in cultivated soils has been more obvious because contrasting crops, soil amelioration, addition of fertilizers and other management and cultural operations super impose on the differences between fields on a variation already present in a native soil.

The available literature on spatial variation of usual soil survey parameters of mapped soil units or the salient features of the methods of evaluating variability of soil physical and chemical properties is not completed and do not illustrate the specific effect of variability of landscape as a function of its physiographic position.

Owing to the fact that soil properties change gradually across the landscape, investigations of the spatial variation of soil properties over a distance is of great interest. Such studies will help in the better management of agricultural fields and for the improvement of ecological and environmental situations.

The high variability thus maintained within closely related soil groups creates serious difficulties for interpreting patterns of crop response imposed by treatment variables or environmental conditions. Several Scientists (Wallace et al 1982, Costigan et al 1983, Bresler et al 1982) are of the view that powerful statistical techniques are necessary to establish appropriate relationship between field soil variability and crop field variability.

The present study entitled "Fertility investigations on the soils of South Kerala in relation to their physiographic positions" has been undertaken with the following objectives.

1. To trace the changes in the macro and micronutrient status in the different horizons of the soil profiles as a function of the physiographic position.

2. To find out the distribution of organic matter in the soil profiles at different physiographic positions and to study the carbon nitrogen relationship.

3. To study the effect of physiographic position on the physical and physiochemical properties.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The importance of topography as a factor of soil formation responsible for bringing about differences in nutrient status of soils has been well recognised in modern Pedology.

The accumulated information on the vertical and lateral distribution of important plant nutrients in soils of varying topographical situations, but under identical conditions of other soil forming factors are reviewed and presented in this chapter.

Elevation or physiographic position as a pedogenic factor brings about characteristic differences in the physical and chemical properties of soil. Topography modifies the soil water relationship and to a considerable extent influences the erodability of surface soils which in turn will affect many of the soil properties.

Moderate or drastic changes in topography giving rise to differences in elevation of about five to ten metres within a short distance of one kilometre is very common in the hilly tracts of the midland regions of Kerala State.

The effect of slope on soil erosion is, however, drastically influenced by surface characteristics, vegetation and crop residue management. Water run off and soil erosion bring about gradients in several soil physical properties, especially the particle size distribution. Loss of surface soil by sheet erosion depletes the soil body of the weathered mantle which carries the valuable nutrients, organic matter as well as most of the primary and secondary minerals.

Dhruva Narayana and Sastry (1983) in a survey of soil erosion in India have estimated that 180 million ha of red earths and vertisols are losing 4 to 43 t ha^{-1} $year^{-1}$ of fertile top soil by sheet erosion and that an additional 17 million ha are being eroded at the rate of 33 to 80 t ha^{-1} $year^{-1}$ by gully erosion. Murthy and Sankaranarayana (1977) have confirmed these findings in their studies of laterite soils of Siwalies on steep slope of South India.

Based on field experiments, the Kerala Agricultural University has reported that uncultivated bare fallow plots recorded loss of nutrients of the order of 107 kg N, 28.5 kg P_2O_5 and 22.5 kg K_2O/ha during a cropping season

(Anon, 1983). Maximum loss of nutrients was recorded in plots where tapioca was cultivated in mounds. The rate of loss was 44 kg for N, 15 kg for P_2O_5 and 39 kg for K_2O/ha. Maximum retention of rainfall was recorded by tapioca cultivated on ridges across the slope with groundnut as intercrop. Planting tapioca on ridges across the slope with groundnut as intercrop reduced the amount of soil loss and surface run off.

Soil structure (Aggregation)

The structural properties of the soil influence crop growth through their effects on soil moisture properties, soil air, soil temperature and impedence to root development. Eventhough the soil may be fertile, the crop yields will be reduced considerably if the structural properties of the soil are not favourable to air and water movement or root penetration.

Baver (1956) observed significant correlation between percentage of aggregates larger than 0.05 mm and the organic carbon content of the soils.

Ameer (1970) studied a few typical red, black, alluvial and laterite soils of Tamil Nadu upto 40 cm depth and observed significant correlations between coarse sand and stability index and aggregate stability.

Lal (1976) worked on alfisols of Western Nigeria and observed that soil erosion increased the gravel content and decreased the silt and clay contents of the surface horizon.

Loganathan and Krishnamoorthy (1976), from their study of some Tamil Nadu soils, reported that the clay content increased with depth and the maximum was reached in intermediate horizons.

Brunelle et al (1976) have reported that the total non clay fraction (sand plus silt) was consistantly highest in the eluvial horizon and lowest in the illuvial horizon of certain solonetzic soils.

Manickam (1977) studied the textural composition of the laterite soils of Tamil Nadu. The soil profiles exhibited heterogenity with reference to the textural fractions. The clay registered an increasing trend and the sand fractions registered a decreasing trend with depth.

Organic carbon and C/N ratio

Unnikrishnan (1961) in his studies on laterite soils of Tamil Nadu recorded a significant positive correlation between rainfall and organic carbon under humid conditions.

Drowpathi Devi (1963) found a positive correlation for organic carbon with nitrogen in Kerala soils.

Sadanandan Nambiar (1963) in his studies on major soil groups of Madras State observed a close relation between organic carbon and rainfall which he attributed to the direct effect of increased vegetation.

Ramaswamy (1966), while studying the properties of Madras soils, noticed an increase in the major plant nutrients, N, P and K with high organic matter content in the soil.

Tabatabai and Hanway (1968) while studying the chemical and physical properties of different sized natural aggregates of Iowa soils reported that organic carbon increased as the aggregate size decreased.

Biplab Chakravarthy and Chakravarthi (1980) studied the organic components of twelve soils from places of varying altitudes and climatological conditions. They reported a significant decrease in clay and organic matter contents with increase in altitudes.

Nutrient status

a. Nitrogen:

Hockensmith and Tucker (1933) found that the nitrogen content of Rocky mountain soils of Colorado increased with increase in elevation.

Jenny and Leonard (1934) showed that nitrogen increased continuously with increasing rainfall. From studies on Hawaiian soils, Dean (1937) reported that the nitrogen content of soils increased with increasing elevation and carbon content of the soil.

Jenny (1941) has found that the general trend of the nitrogen-depth curve for tropical soils was exponential. He also showed that nitrogen generally penetrated deeper into the soil with increase in rainfall.

Jenny and Raychaudhuri (1958) observed an increase of nitrogen in Indian soils with an increase in the mean annual precipitation in hot coastal areas, as well as in the cold Himalayan belt.

Unnikrishnan (1961) studied the South Indian laterite soils and pointed out that the nitrogen content increased with rise in rainfall. Mahalingam (1962) observed an overall increase in nitrogen content with increase in mean annual rainfall. Under such conditions, the C/N ratio showed a definite tendency to become wider.

Donskihk (1966) has noted that the total nitrogen content of the top 120 cm layer of upper peat was 5.45 t/ha and that of lower peat, 36.85 t/ha. Organic nitrogen in the surface horizon of upper peat constituted 47.69 percent of the total nitrogen.

Snedon et al (1972) studied some Alpine soils and found that the total nitrogen was the greatest in the surface horizons and decreased with depth.

Usha and Jose (1982) have reported that with increase in acidity of Kerala soils, the content of organic carbon, as well as total and available nitrogen showed a tendency to increase. The content of organic carbon in the soil was found to be significantly and positively correlated with clay content. Organic carbon content showed a positive and significant correlation with total nitrogen of soil. On an average, 10.82 percent of total nitrogen in soil was retained in the available form. The N/aN ratio increased with increase in organic carbon content. The relationship however, was not linear.

Patel et al (1983) after studying the fertility status of three locations in relation to geographic situations and cultivation practices, found that the soils of the foot hills of mount Girnar had the highest nitrogen content. The nutrient content normally decreased with increasing depth.

Phosphorus

Karim and Khan (1956) in a study on the vertical distribution of nutrients in the soils of East Pakistan found that phosphorus increased upto a depth of 7" and then decreased sharply upto 35".

Ray Chaudhuri and Landley (1960) have found that soils containing high amounts of clay and silt retained more phosphorus and showed only a low availability of this element.

Wild (1961) in a pedological study of twelve soils of Australia found that there was no correlation between loss of phosphorus and rainfall.

Sadanandan Nambiar (1963) in his studies on the soil groups of Madras State observed that total phosphorus content of soils increase with increase in rainfall. The relation was more prominent in red and Nilgiri soils which was attributed to the high organic matter content of these soils.

Koshy and Britomutunayagom (1965) from their study on Kerala soils reported that the level of total phosphorus varied from 0.024 to 0.256 percent. The phosphorus fixing capacity also varied widely, acid soils with high sesquioxides having high fixation capacity. Downward movement of phosphorus in Kuttanad soils was found to be very low.

Available phosphorus

Ghani and Aleem (1943) from their studies on the distribution of phosphorus in some Indian soils concluded that the availability of phosphorus was a function of pH.

Non availability in acid soils was attributed to the formation of iron and aluminium phosphates and organic phosphorus.

Koshy and Britomutunayagom (1961) studied the soils of Travancore-Cochin and found that most of the soils were poor in available phosphorus. In laterite soils with pH 6.5, phosphorus was present largely in combination with iron and aluminium.

From studies on the fractionation of soil phosphorus of four South Indian soils, Janardhanan Nair (1961) reported that iron and aluminium phosphates were high in laterite soils and low in red and black soils. In red soils all forms of phosphorus were very low but they were distributed equally.

Studies on the vertical distribution of total and available P in the typical soil profiles of Gujarat have shown that the top layers were richer in both the fractions than the subsoil horizons (Patel and Mehta 1962).

In contrast to nitrogen, phosphorus tends to be immobile in soil because of its precipitation by Ca, Al and Fe. Based on studies of soil P fractions of Vindhyan soils of Mirzapur district, Gupta and Singh (1971) showed that total P was maximum in the surface horizons which decreased with depth in the soil profile.

Chibba and Sekhon (1973) observed that available P did not show any definite trend of increase or decrease with depth in the soil, eventhough it was higher in the surface soils of the two profiles studied. It varied from 3.9 to 85.1 kg/ha.

Studies on the movement of N, P and K in the soils of Kerala (Anon, 1982) have indicated that among the three nutrients, P showed the least mobility in sandy soil. In the alluvial and laterite soils, movement of P down the soil column was practically nil.

Patel et al (1983) have studied the soils of foot hills of Mount Girnar in relation to geographic situations and cultivation practices and reported that the P content was in general medium to high. The nutrient content normally decreased with increasing depth.

Potassium

The actual distribution of potassium in soil profiles has been reported to be dependent upon the homogenity of the parent material with regard to type and abundance of potassium bearing material and the particular soil forming processes involved.

Karlson (1952) noticed that in Swedish soils, the total potassium content was more in the subsoil horizon than in the top soil and it increased with clay content.

Karim and Khan (1956) in their study on the vertical distribution of potassium in the soils of East Pakistan found that it decreased to a depth of 7" and thereafter it increased progressively upto 35".

In the red soils of Coorg (Karnataka State) the percentage of total potassium increased from the surface soil upto parent material except in the second horizon, whereas in the red soils of Madurai (Tamil Nadu) the total potassium content increased with increasing depth from 2.06 to 2.67 percent (Dhanapalan Mosi, 1960).

Halim et al (1963) investigating the potassium status in the U.A.R. soils have found that total potassium varied from 2.5 me/100 g in coarse textured soils to

15.0 me/100 g in fine textured soils. It was highly correlated with clay percentage and exchangeable potassium.

Verma and Verma (1968) have found that available (water soluble and exchangeable) K varied from 0.064 to 4.65 me/100 g in individual samples collected from 24 districts of Madhya Pradesh.

An increase in the total potassium content with increase in depth was also reported by Balaguru (1970) for red and alluvial soils of Tamil Nadu.

Kuntze and Leisen (1970) reported that the levels of HCl soluble potassium increased with increasing clay content.

Kadrekar (1973) observed that the contents of exchangeable, available and water soluble forms of potassium in acid soils declined with the depth of the profile.

Effect of rainfall and elevation on potassium content of soil.

As early as 1914, Hilgard reported that the relative migration and leaching of potassium and sodium in soils was definitely more pronounced in humid regions with heavy rainfall than in arid regions of scanty rainfall.

Metson (1960) has indicated that potassium being a highly mobile lithosphere element, could be easily leached and washed out of the profile.

However, Unnikrishnan (1961) could not observe any regular relationship between soil potassium content and rainfall and elevation.

Potassium was found to be higher in soils of low rainfall areas than in soils from heavy rainfall areas. But there was no regular correlation between potassium content and rainfall and elevation (Earnest Dhanaraj, 1966).

Bolan (1976) concluded that there was a decrease in total potassium with increasing depth in most of the profiles which could be due to a decrease in the organic matter content associated with increase in depth.

Verma and Verma (1968) have reported that potassium was correlated with pH, $CaCO_3$ and organic carbon contents.

Decrease in exchangeable potassium with increase in depth of the soil profile was noticed by Igbounamba-Oparch (1972) and Solov'ev (1974) for Agodi and Adio soils and Chernozem and Chestnut soils respectively.

Studies of the distribution of different forms of potassium in red soils conducted at the Tamil Nadu Agricultural University (Anon, 1975) have shown that the water soluble and exchangeable K contents of red calcareous and non-calcareous soils of the Coimbatore district (Tamil Nadu) decreased with depth, whereas non-exchangeable and total K contents increased with depth.

Studies on the movement of potassium in soils of Kerala (Anon, 1982) have shown that mobility of K in the upper layers is greater which increased the accumulation above the compacted layer. Sodium citrate was found to be effective in reducing the movement of K across soil columns.

Calcium

On an analysis of the soils from the arid and humid regions of the United States, Hilgard (1914) found that hydrochloric acid dissolved more of total material from arid soils than from the humid soils. In addition, the arid soils were higher in content of calcium, both in absolute amounts and in relation to alumina. He stated that the higher rainfall of the humid regions impoverished the surface soil through leaching.

Alway (1916) in his studies on Nebraska loess soils found a pronounced negative correlation between annual precipitation and hydrochloric acid soluble as well as insoluble calcium.

Bhuiyan et al (1961) after studying the profiles of high land and medium land of the sub tropical Khiyar Tract in East Pakistan concluded that total and exchangeable calcium were higher in the high land than in the medium land. The distribution of calcium with in the profiles was uniform and there was no marked variation between the profiles.

Kurashima et al (1981) observed that removal of chemical elements by leaching was large for CaO and Na_2O. Both CaO and Na_2O were very mobile and were leached rapidly in the Andosols under humid climatic conditions. They determined the mobility sequence of the major chemical elements in the top soils of Andosols as follows:

$$CaO > Na_2O > SiO_2 > MgO > Al_2O_3 > Fe_2O_3 > K_2O$$

Magnesium

The level of magnesium in soils depends to a large extent on soil type, rainfall, elevation, particle size distribution and organic matter content. In a study of fifty five North German soils, Schroeder and Zahiroleslam (1963) found that total magnesium decreased from 0.5 percent in marsh soils to 0.05 percent in podsols.

In the acid soils rich in organic matter relatively less magnesium was lost by leaching (Carolus 1935). Prince et al (1947) stated that magnesium deficiency was caused in soils eventhough the soils were rich in organic matter but light in texture and acidic.

Bhuiyan et al (1961) after studying the profiles of high land and medium land of the sub-tropical Khiyar Tract in East Pakistan stated that Mg content is very low at the surface but increases with depth.

Acute magnesium deficiency has been reported and confined in highly leached soils at higher elevations and high rainfall areas (Messing 1974).

Magnesium is reported to exhibit an exponential relationship with elevation. Its reciprocal was found to give linear positive relationship with elevation (Mathan 1979).

Shoji and Yamada (1981) postulated that formation of 2:1 mineral is the primary factor influencing the relatively low mobility of MgO in the soil.

Iron

Ting and Yu (1958) observed that iron content was the highest in the illuvial horizon and much more than in the gley horizon.

Narayana Pisharody (1965) found that in the rice soils of Kerala the total iron content was much higher in the sub soil than in the surface soil.

Balaguru and Dhanapalan Mosi (1972) have reported that the black soils of Tamil Nadu were rich in total iron and showed a decreasing tendency with depth. They have also stated that Tamil Nadu soils contained 2.5 to 6.1 percent of total Fe.

Available Iron

Bhumbla and Dhingra (1964) and Follett and Lindsay (1971) have reported a decrease of available iron content with depth in the soil profile.

Balaguru and Dhanapalan Mosi (1972) showed that the available iron content was more in alluvial soil and it decreased with depth.

Fatch Lal and Biswas (1974) observed that available iron was concentrated on the surface of well drained soils, whereas in poorly drained soils it was concentrated in lower horizons.

According to Velayuthan (1974) the available Fe showed an irregular distribution with depth. Randhawa and Takkar (1975) reported that the available Fe content was higher in the surface soils.

Manganese

Distribution of Manganese in soils

Kelley (1909) noticed that manganese content generally decreased with depth in the soil profile.

Similar observations were made by Blair and Prince (1936).

However, Hoon and Dhawan (1943) have reported that total manganese content increased with depth.

Biswas (1953) reported that the distribution of total manganese in black soils was either uniform throughout the profile or decreased slightly with depth.

Randhawa et al (1961) showed that in soils of the Punjab, total Mn increased with depth of profile, whereas the other forms of the element decreased.

Narayana Pisharody (1965) found that in the rice soils of Kerala, the sub soils were richer in total manganese than the surface soils both under waterlogged and dry conditions.

Kanwar and Randhawa (1967) studied the profile samples from different parts of India and showed that the distribution of total manganese in soils was not according to any regular pattern. In calcareous soils and soils of the arid region the distribution of Mn was more or less uniform down the profile, whereas in some of the black cotton soils and the soils of Rajasthan, there was a decrease in the levels of this element with depth.

Rajagopalan (1969) found that the total Mn content in the soils of Kerala decreased with depth in all soil groups except the laterites where the intermediate layers contained the highest amount.

Follett and Lindsay (1971) have reported a uniform distribution of total manganese in red and alluvial soils. Similarly, Biswas (1951, 1953, 1955) has also observed a uniform distribution of available Mn in the profiles of calcareous, arid and pre humid regions.

Randhawa et al (1961), Follett and Lindsay (1971), and Fatch Lal and Biswas (1974) have reported that the available Mn content decreased with depth. However, an irregular distribution of available Mn throughout the profile was reported by Velayuthan (1974).

COPPER

The total copper in Indian soils has been reported to range from 1.8 to 960 ppm (Randhawa and Takkar 1975). The content of total Copper in the red soils of Coimbatore has been found to vary between 178.0 and 374.0 ppm (Rajendran, 1974).

Pack et al (1953) observed that the A horizon of the soils was generally higher in total copper content than the B horizon, indicating the removal of copper from the lower horizons by the plant roots and subsequent deposition on the surface as a constituent of organic matter.

According to Zagota et al (1961) and Kabata Pendias (1968), total copper content in the surface soils was higher than that of the sub surface soils. Mehta et al (1964) and Bandopadhya and Adhikari (1971) have found that total copper in the black cotton soil was maximum in the surface layer and it decreased with depth in the profile.

Revikumar Praseedom (1970) has reported that the total copper content of the laterite soils of Kerala ranged from 9.0 to 78.0 ppm and the distribution of this element in the profile showed an accumulation in the surface. Valsaji (1972) has reported a distinct decrease in the total copper content with depth.

Kavimandan et al (1964) found that available copper was more at the surface and continued to decrease with increasing depth.

Mehta et al (1964), Rai and Mishra (1969), Bandopadhya and Adhikari (1971) and George Varghese (1971) observed that available copper accumulated in the surface and it decreased with depth.

According to Revikumar Praseedom (1970) there was no regularity in the downward distribution of available copper in the different soil profiles of Kerala.

Fatch Lal and Biswas (1974) observed that the available copper was uniformly distributed in the profiles of relatively less weathered desert and alluvial soils. It increased with depth in poorly drained soils and decreased with depth in well drained soils.

Zinc

The total zinc content of soils has been reported to vary from 20.0 to 95.0 ppm in soils of Western India (Nair and Mehta, 1959), 20.0 to 95.0 ppm in Gujarat soils (Mehta et al 1964), 58.0 to 72.2 ppm in soils of Maharashtra (Ray Chaudhuri and Datta Biswas, 1964), 55.0 ppm in Punjab soils (Randhawa and Kanwar, 1964) and 6.2 to 11.5 ppm in Tamil Nadu soils (Balasundaram et al 1973). In the laterite soils of Kerala, the zinc content varied from 2.5 to 25.0 ppm (Revikumar Praseedom, 1970). The available zinc has been reported to decrease with increase in pH of the soil (Camp, 1945).

The content of zinc is reported to decrease with depth.

Agarwala (1963) noticed an accumulation of zinc in a horizon at a depth of 1.5 to 3.0 feet in most of the soils from Uttar Pradesh. In a few profiles he observed a surface accumulation of zinc which decreased with depth.

Datta Biswas and Dakshinamurti (1958), Nair and Mehta (1959), Ravikovitch et al (1961), Tiwari and Mishra (1964), Bhumbla and Dhingra (1964), Tripathi et al (1969), Bandopadhya and Adhikari (1971), Sankar and Dwivedi (1972) and Daulatram (1973) have reported results to this effect.

However, Revikumar Praseedom (1970) has reported that there is no regularity in the downward distribution of total zinc in the soils of Kerala.

George Varghese (1971) found that the total and available zinc in the soils of Kerala varied from 15.0 to 92.50 and 1.20 to 6.48 ppm respectively and it decreased with depth in most of the profiles. But Follett and Lindsay (1971) reported uniform distribution of total zinc in Colorado series.

Bandopadhya and Adhikari (1971), Follett and Lindsay (1971) and Daulatram (1973) have also made similar observations.

According to Valsaji (1972) there was no significant variation with depth in the distribution of total and available zinc in the soils of Trivandrum district.

Velayuthan (1974) showed an irregular distribution of available zinc.

MATERIALS AND METHODS

MATERIALS AND METHODS

The effect of physiographic position of the land on the nutrient composition and physical properties of soils was studied by selecting twelve locations in the districts of Quilon and Trivandrum. These locations were at an altitude of 20 to 150 metres above mean seal level along the slopes of hills and showed a moderate gradient, often ending up in level paddy fields in the bottom areas. These regions were not influenced by rivers or canals and all the soils showed good drainage both externally and internally except at the lowest reaches where waterlogged paddy fields were situated.

The details regarding the location of the sites of study, their altitude, degree of slope etc. are given in table 1 and figure 1.

The rainfall data on these sites for the last five years (1980 - 1984) collected from the Meteorological Centre, Trivandrum are also presented in table 2.

Vegetation

Most of the basins (lower reaches) are under paddy

Table 1. Physiographic data and locations.

Sl. No.	Location name	District	Altitude (metres above MSL)	Degree of slope
1	Anchal	Quilon	40	6
2	Kallayam	Trivandrum	20	14
3	Kulathupuzha	Quilon	75	27
4	Neyyattinkara	Trivandrum	75	15
5	Ottasekharamangalam	Trivandrum	50	15
6	Palode	Trivandrum	30	7
7	Punalur	Quilon	35	7
8	Thalavur	Quilon	40	8
9	Uzhamalakkal	Trivandrum	75	15
10	Vellarada	Trivandrum	150	10
11	Vembayam	Trivandrum	45	15
12	Vithura	Trivandrum	40	6

Source: Directorate of Soil Conservation, Trivandrum.

FIG. 1 _ LOCATION MAP

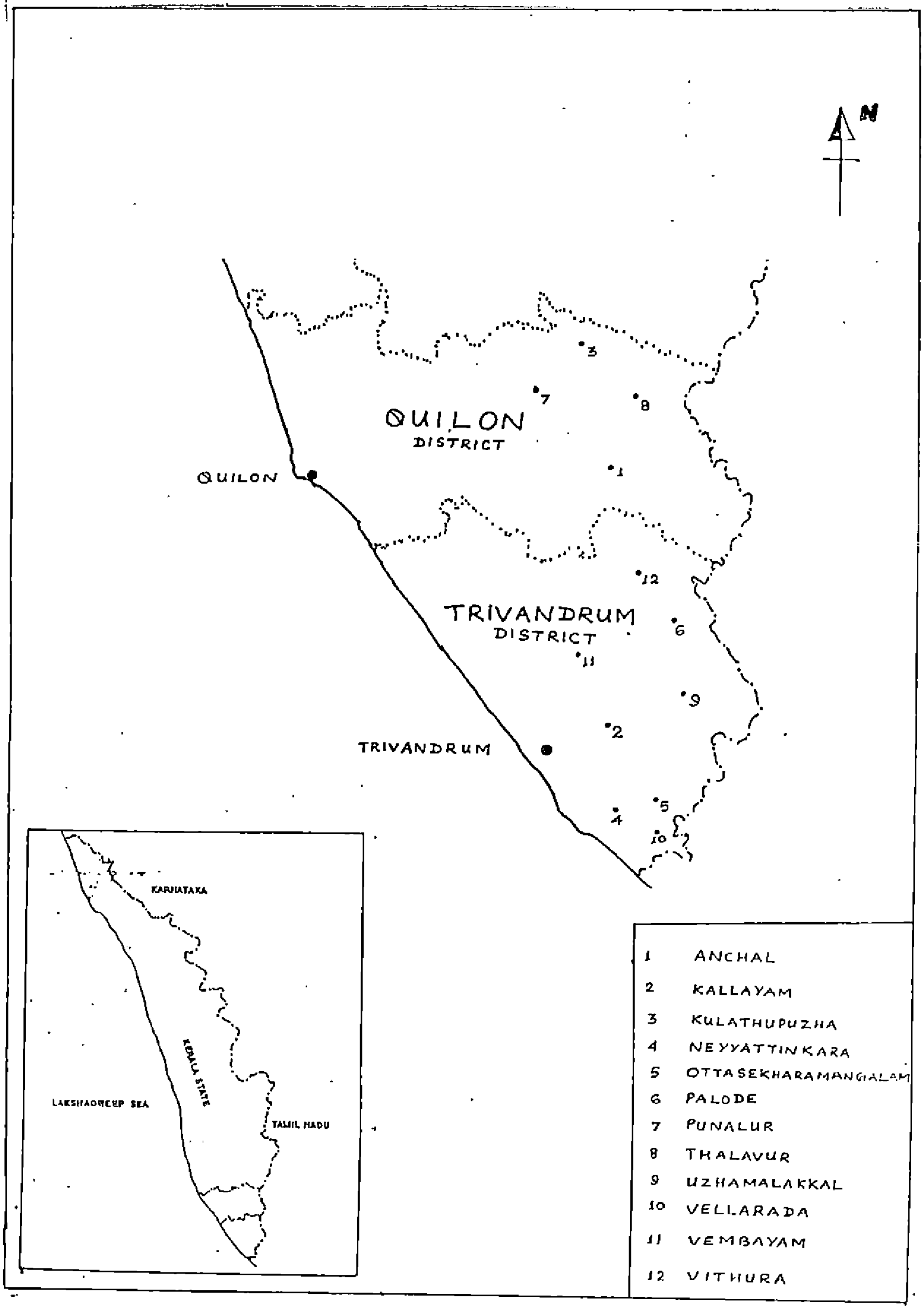


Table 2. Rainfall data (in mm)
Trivandrum District (1980-1984)

Month	1980	1981	1982	1983	1984
January	NIL	40.5	NIL	NIL	65.1
February	NIL	31.4	NIL	NIL	128.2
March	21.9	35.1	16.1	NIL	151.0
April	92.6	121.1	82.0	119.9	297.0
May	128.9	150.8	284.7	106.1	153.7
June	361.9	479.9	428.6	229.8	205.5
July	178.0	174.4	151.8	100.3	126.0
August	163.2	145.8	109.2	237.9	21.1
September	179.9	361.6	17.1	226.3	40.2
October	207.3	300.9	164.8	67.6	205.1
November	150.6	297.0	131.0	107.3	71.8
December	81.3	29.8	23.3	161.2	2.7
TOTAL	1565.6	2168.3	1408.6	1356.4	1467.4
Mean	130.4	180.6	117.3	113.0	122.2

Quilon District (1980-1984)

Month	1980	1981	1982	1983	1984
January	NIL	NIL	NIL	NIL	1.0
February	NIL	65.4	NIL	NIL	98.6
March	39.0	84.0	136.8	NIL	173.2
April	239.8	210.2	175.0	44.8	347.4
May	118.2	166.8	375.0	70.2	178.0
June	487.6	859.2	581.6	263.2	465.0
July	471.2	374.4	261.0	357.0	481.0
August	267.2	339.4	202.8	425.2	140.8
September	207.8	423.0	31.8	322.2	253.2
October	202.4	275.0	256.0	102.6	254.8
November	NIL	114.4	265.0	372.0	99.0
December	113.8	2.4	NIL	129.8	67.6
TOTAL	2147.0	2914.2	2285.0	2087.0	2559.6
Mean	178.9	242.8	190.4	173.9	213.3

Source: India Meteorological Centre, Trivandrum.

cultivation during Virippu (Kharif) and Mundakan (Rabi) seasons. The middle reaches are cultivated to banana, pepper, coconut, tapioca etc., and except in a few locations the upper reaches are cultivated with perennial crops like coconut, rubber etc. in addition to common annual crops.

Collection of soil sample

In each of the twelve locations, three profiles were exposed; one from the uppermost elevation, second from the middle reaches and the third from the lowest reaches. Since horizon differentiation within the profiles was not marked due to their wavy and overlapping nature, two soil samples only were collected from each profile at two prescribed depths of 0 to 20 cm and 20 to 40 cm.

Soil Analysis

Preparation of soil samples

The air dried soil samples were gently powdered and passed through 2 mm sieve and stored for further analysis.

Gravel content

The gravel content as retained in the 2 mm sieve was estimated and the results were expressed as percentage.

Textural composition

The proportion of the various size fractions of the soil was determined by carrying out the mechanical analysis of soil as outlined by Jackson (1967). From the percentage of sand, silt and clay, the texture of the soil was obtained by reference to the textural diagram (USDA, 1955).

Aggregate analysis

The proportion of water stable aggregates in the different soil samples was estimated by the wet sieving method as described by Yoder (1936). For this, 100 g of air dried and undisturbed soil sample was kept on the top sieve of a set of sieves, having apertures of 4, 2, 0.5, 0.25 and 0.1 mm. These were subjected to wet sieving for 10 minutes. The weights (oven dry) of aggregates in each of the sieve were determined.

Soil reaction (pH)

The pH of 1:2.5 soil suspension was determined using a glass electrode (Piper, 1966).

Chemical properties

The soil samples were analysed for the following chemical parameters by the methods noted against each.

1. Total nitrogen	Micro-kjeldahl method	Jackson (1967)
2. Total phosphorus	Chlorostannous reduced molybdo phosphoric blue colour method.	Jackson (1967)
3. Total potassium	Flame emission Spectro photometry using sulphuric acid extract.	Jackson (1967)
4. Available Nitrogen	Alkaline permanganate method.	Subbiah and Asija (1956)
5. Available phosphorus	Bray's extractant No. 1.	Jackson (1967)
6. Available potassium	Flame emission Spectro photometry using neutral normal Ammonium Acetate extract.	Jackson (1967)
7. Organic carbon	Walkley and Black's titration method.	Jackson (1967)

Total and available calcium and magnesium

The total calcium and magnesium were determined in the perchloric acid extract of the soil and the available

Ca and Mg in the ammonium acetate leachate (Jackson, 1967). The extracts were fed into an Atomic Absorption Spectrophotometer model P-E.3030 and the spectrum of absorption was determined at the following wave lengths.

Calcium	422.7 nm
Magnesium	285.2 "

Total and available Iron, Manganese, Copper and Zinc

The total micronutrients were determined in the perchloric acid extract of the soil (Holmes, 1945) and the available micronutrient status in 0.005 M DTPA extract (Lindsay and Norwel, 1978).

The extracts were fed into an Atomic Absorption Spectrophotometer model P-E.3030 and the spectrum of absorption was determined at the following wave lengths.

Iron	248.3 nm
Manganese	279.5 "
Copper	324.8 "
Zinc	213.9 "

Statistical Analysis

Correlations were worked out to establish the relationship between the three reaches in a location and the physico chemical characteristics of the soils under study. Simple correlation were also worked out between the different soil properties (Panse and Sukathma, 1967).

RESULTS

RESULTS

The effect of physiographic position of the land on the nutrient status and other physical properties of soils situated at different slopes and elevations has been investigated. Twelve locations in Trivandrum and Quilon districts were selected for this study and the results of analysis of the soil samples collected are presented in this chapter.

A. PHYSICAL PROPERTIES OF SOILS

Gravel

The content of gravel in the samples from different locations showed a wide variation and ranged from 5.8 in the samples from Anchal to 82 percent in Punalur (Table 3). It was significantly higher in the upper reaches when compared to their corresponding lower reaches. There was no significant difference in the content of gravel among the samples from the two depths and no interaction was noticed either between slope and depth or soil and depth.

Particle size distribution

a. Coarse sand

Appreciable difference was evident in the content

Table 3. Physical properties of soils - Gravel content (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	8.4	5.8	28.0	22.4	52.4	70.4
2	Kallayam	38.0	21.0	33.0	23.8	43.0	37.0
3	Kulathupuzha	18.6	19.4	24.0	35.0	51.0	61.4
4	Neyyattinkara	30.0	28.0	35.8	39.0	34.2	39.4
5	Ottasekharamangalam	9.0	17.0	49.0	65.0	49.0	53.0
6	Palode	15.0	9.0	50.0	49.0	57.0	75.0
7	Punalur	18.0	24.0	30.4	82.0	48.4	40.4
8	Thalavur	11.4	23.4	54.4	54.0	55.4	55.0
9	Uzhamalakkal	18.0	19.0	34.0	32.8	37.0	40.0
10	Vellarada	20.0	19.0	47.4	25.0	53.0	50.0
11	Vembayam	17.0	13.6	38.4	29.4	35.0	25.0
12	Vithura	17.0	12.0	22.0	15.0	43.0	27.0
	Mean	18.3	17.6	37.2	39.3	46.5	47.8

CD between soils x depth = 15.0

" " reaches x depth = 7.0

" " soils x reaches = 18.0

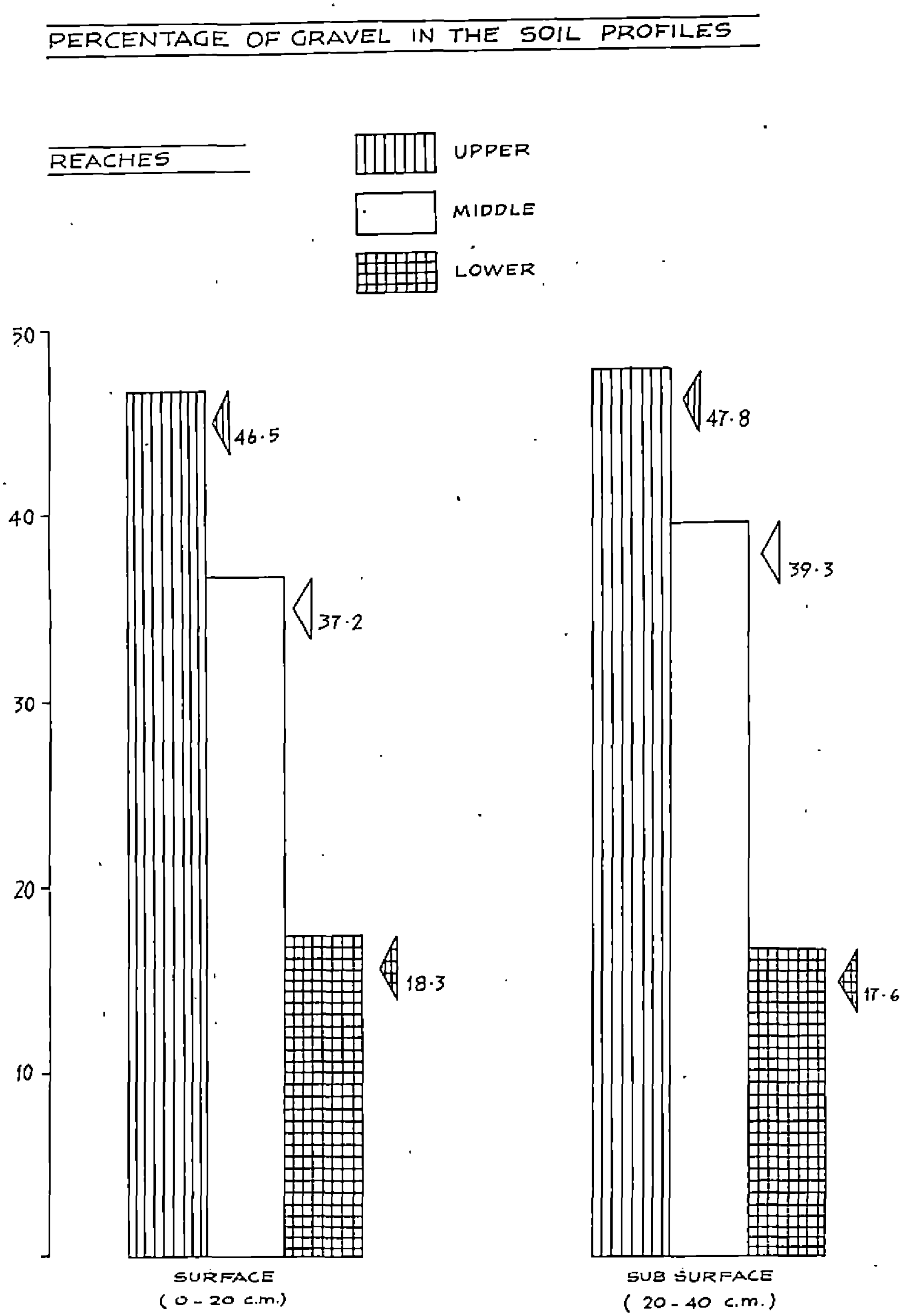

PERCENTAGE OF GRAVEL IN THE SOIL PROFILES
REACHES
UPPER
MIDDLE
LOWER
50
40
30
20
10
46·5
37·2
18·3
47·8
39·3
17·6
SURFACE
(0 - 20 c.m.)
SUB SURFACE
(20 - 40 c.m.)

FIG. 2

of coarse sand in the soil samples collected from the different locations. The values ranged from 25 percent in the samples from Vembayam and Ottasekharamangalam to 72 percent in the Anchal soil (Table 3a).

Significantly higher amount of coarse sand was recorded for the lower reaches. Much difference in the coarse sand content in the upper and middle reaches could not be observed, eventhough the upper reaches showed a lesser content.

b. Fine sand

The content of fine sand in the different samples varied from 4 to 28 percent (Table 3b) and, it was significantly higher in the middle reaches. Soil from Kallayam recorded the highest value of 28 percent and soil from Punalur and Vembayam recorded the lowest value.

c. Silt

The analysis showed that the silt content varied from 10 to 40 percent in different locations (Table 3c). Generally, the lower reaches in all locations recorded less of silt compared to the higher reaches. It was

Table 3a. Physical properties of soils - Coarse sand (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	62	72	60	60	30	54
2	Kallayam	51	69	33	40	40	41
3	Kulathupuzha	40	45	52	50	36	32
4	Neyyattinkara	30	26	48	51	47	56
5	Ottasekharamangalam	68	60	44	35	25	45
6	Palode	70	68	37	42	43	34
7	Punalur	55	64	34	36	42	52
8	Thalavur	54	59	53	32	34	33
9	Uzhamalakkal	43	33	37	49	37	36
10	Vellarada	45	47	38	31	46	45
11	Vembayam	45	50	41	30	36	25
12	Vithura	62	65	65	59	56	53
	Mean	52.08	54.83	45.17	42.92	39.33	42.17

CD between soils x depth = 15
" " reaches x depth = 8
" " soil x reaches = 18

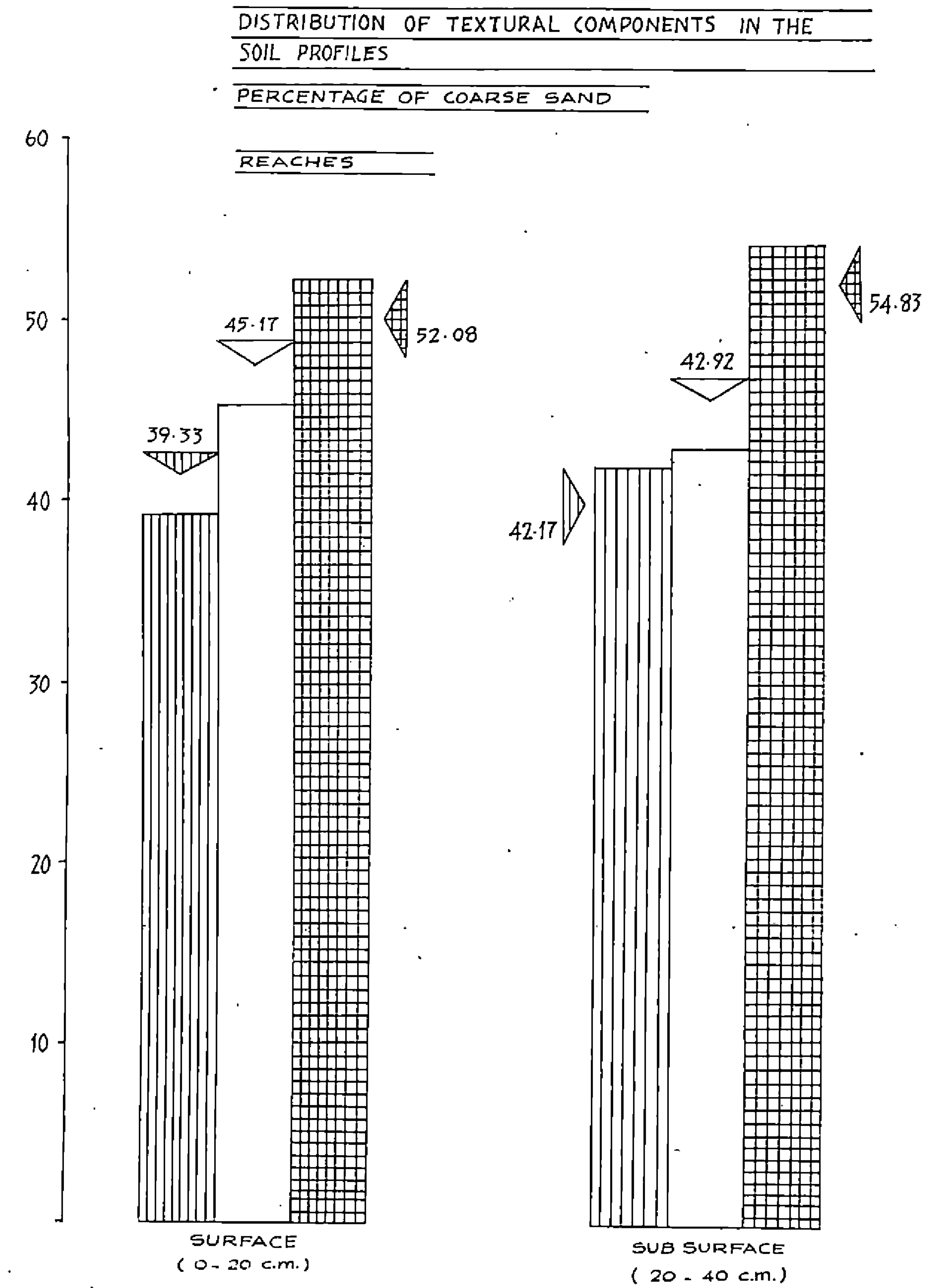

DISTRIBUTION OF TEXTURAL COMPONENTS IN THE SOIL PROFILES
PERCENTAGE OF COARSE SAND
REACHES
60
50
40
30
20
10
39·33
45·17
52·08
42·17
42·92
54·83
SURFACE
(0 - 20 c.m.)
SUB SURFACE
(20 - 40 c.m.)

FIG. 3

Table 3b. Physical properties of soils - Fine sand (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	10	12	17	20	25	15
2	Kallayam	15	14	23	28	17	9
3	Kulathupuzha	17	14	18	6	16	12
4	Neyyattinkara	12	16	15	16	12	10
5	Ottasekharamangalam	5	11	20	23	20	10
6	Palode	10	11	16	15	18	15
7	Punalur	5	4	11	12	12	4
8	Thalavur	10	11	9	10	12	9
9	Uzhamalakkal	7	10	12	13	9	9
10	Vellarada	11	13	15	14	11	11
11	Vembayam	7	11	12	10	14	4
12	Vithura	14	17	11	13	9	8
	Mean	10.25	12.00	14.92	15.00	14.58	9.67

CD between soils x depth = 4

" " reaches x depth = 2

" " soils x reaches = 5

DISTRIBUTION OF TEXTURAL COMPONENTS IN THE SOIL PROFILES

PERCENTAGE OF FINE SAND

REACHES

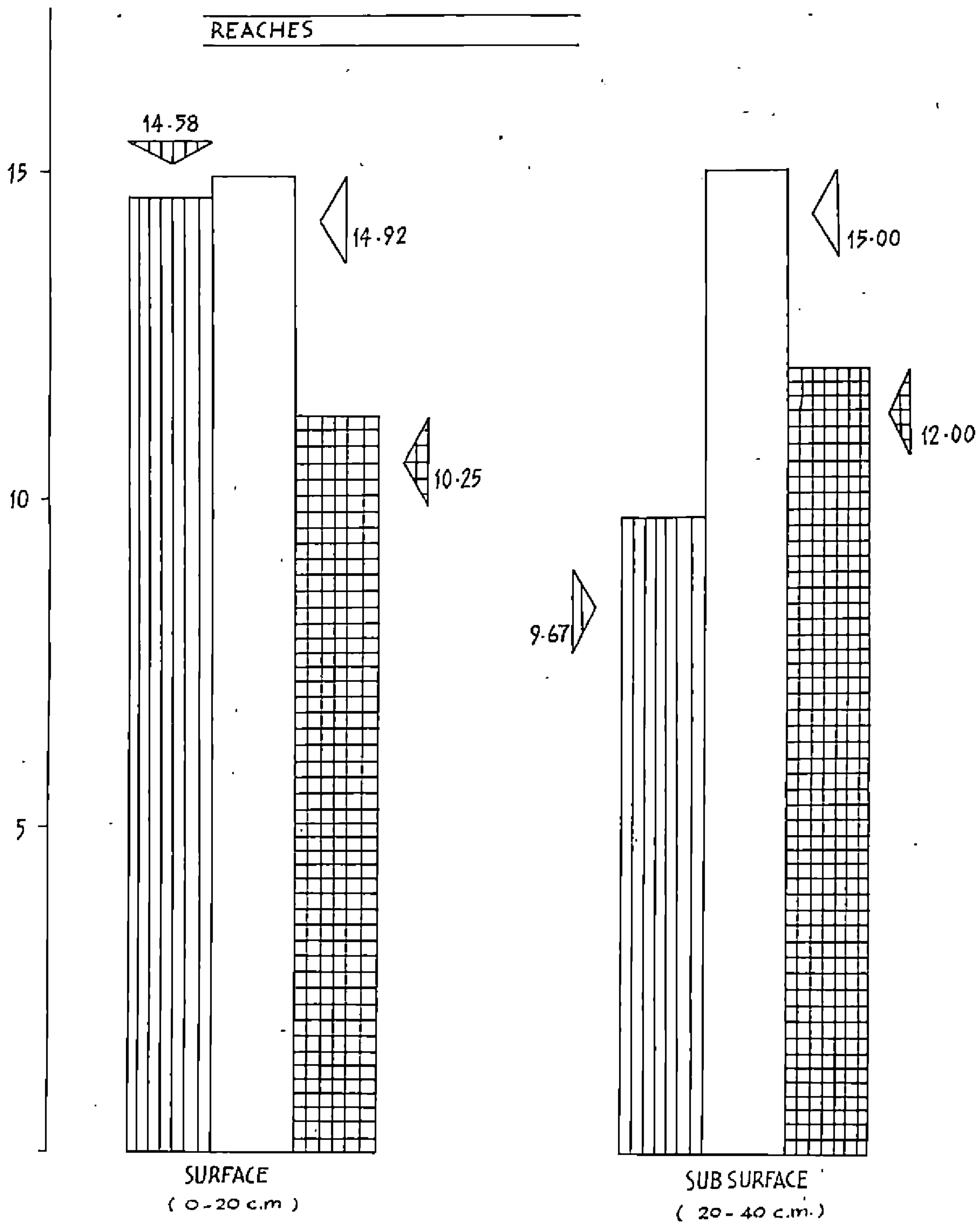


FIG. 4

Table 3c. Physical properties of soils - Silt (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	10	10	10	10	20	10
2	Kallayam	10	10	20	10	20	30
3	Kulathupuzha	10	10	20	10	20	30
4	Neyyattinkara	10	30	10	10	10	20
5	Ottasekharamangalam	20	10	20	30	40	10
6	Palode	10	10	20	20	30	30
7	Punalur	10	10	20	10	10	10
8	Thalavur	10	10	20	20	20	20
9	Uzhamalakkal	20	10	10	10	20	10
10	Vellarada	20	30	30	20	20	10
11	Vembayam	30	20	30	30	30	20
12	Vithura	10	10	10	20	30	10
	Mean	14.17	14.17	18.33	16.67	22.50	17.50

CD between soils x depth = 12.09

" " reaches x depth = 6.04

" " soils x reaches = 14.81

DISTRIBUTION OF TEXTURAL COMPONENTS IN THE SOIL PROFILES

PERCENTAGE OF SILT

REACHES

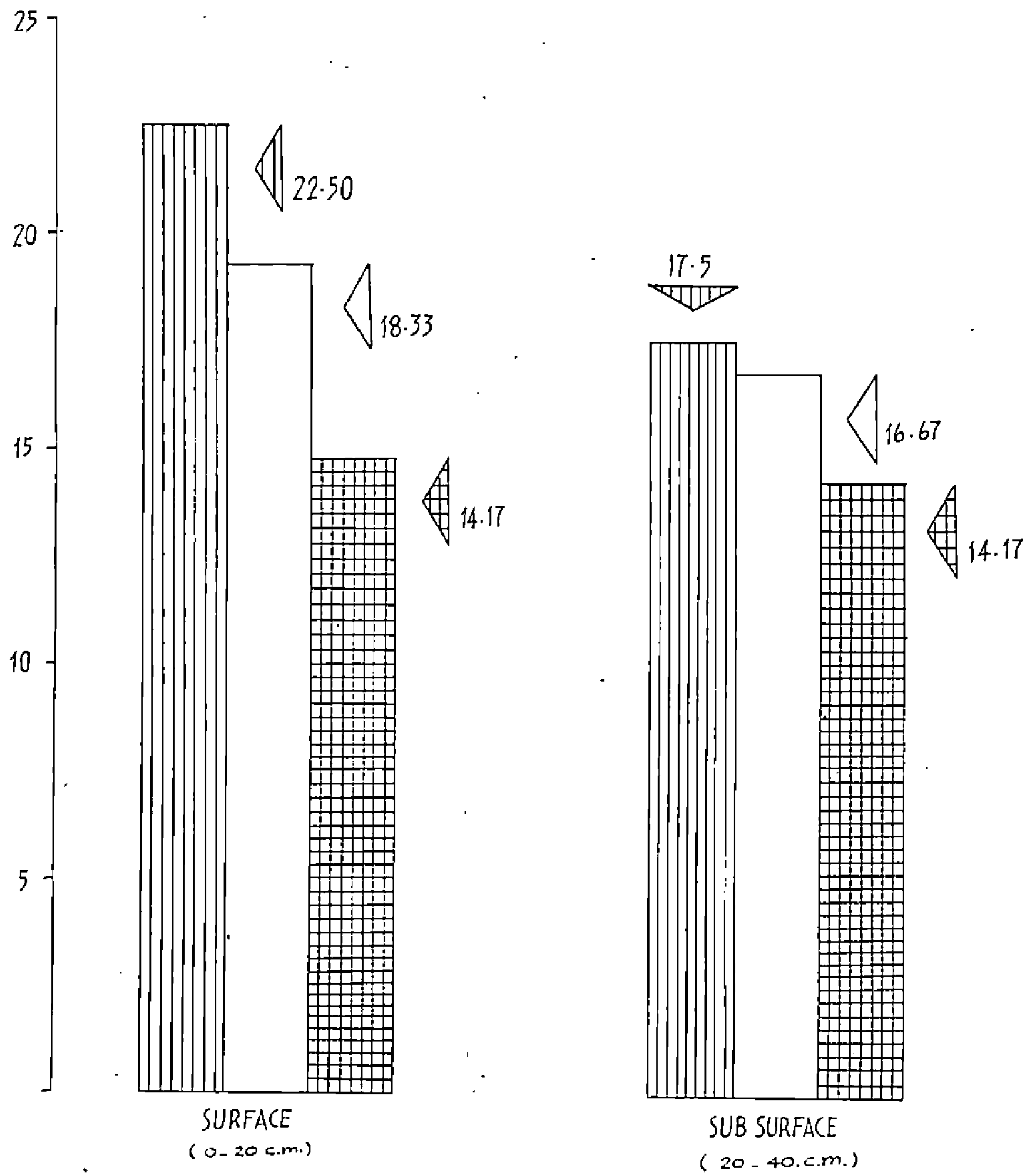


FIG. 5

observed that the silt content was significantly higher in the upper surface at various slopes. Significant variation was also noticed between soils at different slopes.

d. Clay

The content of clay in the different locations ranged from 6 to 51 percent (Table 3d). Maximum clay content was recorded in the upper reaches in Vembayam soil at a depth of 20 to 40 cm.

The interaction effect between soils and depth showed a significant difference in the clay content due to depth factor. The interaction effect between slope and depth also registered a significant difference in the clay content. Soils located at a steeper slope (15 degree) registered more clay content at a depth of 20 to 40 cm than soils existing at a lesser slope of 6 degree.

2. Aggregate analysis (water stable aggregates)

a. Particles of 4 mm size

Wide variation was noticed in the distribution of the aggregates of particles in the different soils.

Table 3d. Physical properties of soils - Clay (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	18	6	13	10	25	21
2	Kallayam	24	7	24	22	13	20
3	Kulathupuzha	33	31	10	34	28	20
4	Neyyattinkara	48	28	27	23	31	14
5	Ottasekharamangalam	10	19	20	20	15	35
6	Palode	10	11	23	20	20	30
7	Punalur	30	22	35	42	36	34
8	Thalavur	26	20	18	38	20	20
9	Uzhamalakkal	30	47	41	28	24	45
10	Vellarada	20	10	20	20	23	34
11	Vembayam	18	19	17	30	20	51
12	Vithura	14	8	24	8	5	29
	Mean	23.42	19.00	22.67	24.58	21.67	29.42

CD between soils x depth = 14

" " reaches x depth = 7

" " soils x reaches = 18

DISTRIBUTION OF TEXTURAL COMPONENTS IN THE SOIL PROFILES

PERCENTAGE OF CLAY

REACHES

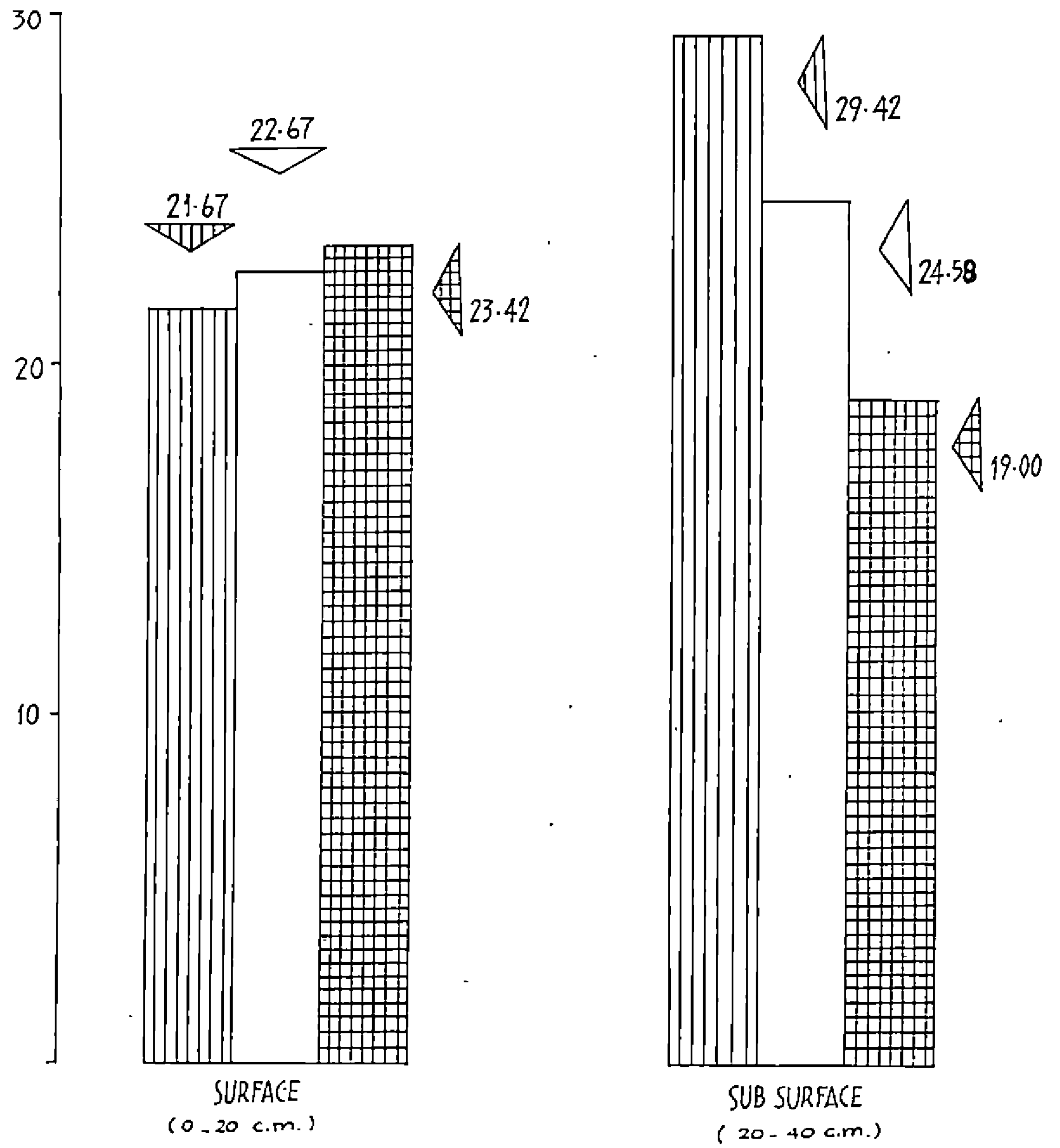


FIG. 6

The 4 mm size particles in the different locations varied from 1 to 67.2 percent. Soils from Anchal recorded the lowest value, while those from Punalur the highest value of 67.2 percent (Table 4a).

It was observed that the lower, middle and upper reaches differed significantly in the content of these particles.

The sub surface soils (20 to 40 cm) of the lower reaches recorded the least and the sub surface soil (20 to 40 cm) of the middle reaches showed the highest values. In the lower reaches the 4 mm sized particles were comparatively less.

No significant difference was noticed in the content of these aggregates at various depths.

b. Particles of 2 mm size

The content of 2 mm size particles varied from 2 to 22 percent and it was significantly higher in the lower reaches (Table 4b).

Highly significant difference existed in the content

Table 4a. Aggregate analysis of soils - particles 4 mm size (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	7.0	1.0	24.0	18.0	54.4	42.8
2	Kallayam	22.8	20.0	2.0	2.0	23.8	20.6
3	Kulathupuzha	4.0	21.0	28.8	36.0	50.0	58.8
4	Neyyattinkara	14.0	2.0	26.0	36.0	54.0	59.0
5	Ottasekharamangalam	2.2	10.2	34.0	46.0	52.0	34.0
6	Palode	2.8	9.0	26.0	42.0	36.4	54.0
7	Punalur	15.6	13.0	36.6	67.2	42.0	36.8
8	Thalavur	5.0	11.4	22.6	36.0	46.2	54.0
9	Uzhamalakkal	14.0	4.6	32.6	38.8	48.0	35.0
10	Vellarada	8.0	15.0	58.0	12.0	32.0	48.0
11	Vembayam	16.6	2.0	20.0	22.0	36.0	20.0
12	Vithura	2.2	11.0	30.0	26.0	32.0	17.2
	Mean	9.5	10.0	28.4	31.8	42.2	40.0

CD between soils x depth = 17.5
" " reaches x depth = 8.6
" " soils x reaches = 21.0

DISTRIBUTION OF WATER STABLE AGGRIGATES

IN THE SOIL PROFILES

AGGREGATES 4 mm SIZE %

REACHES

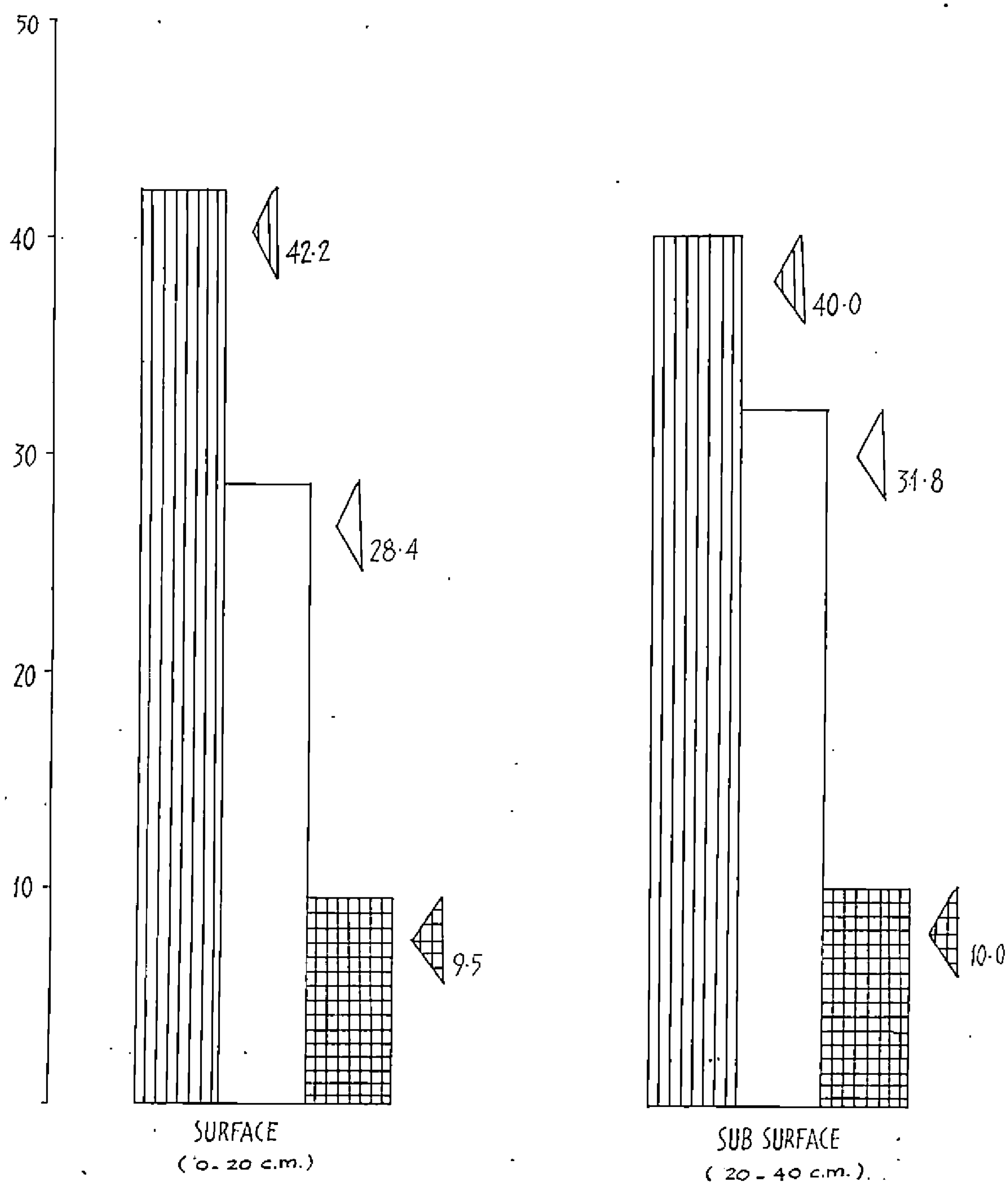
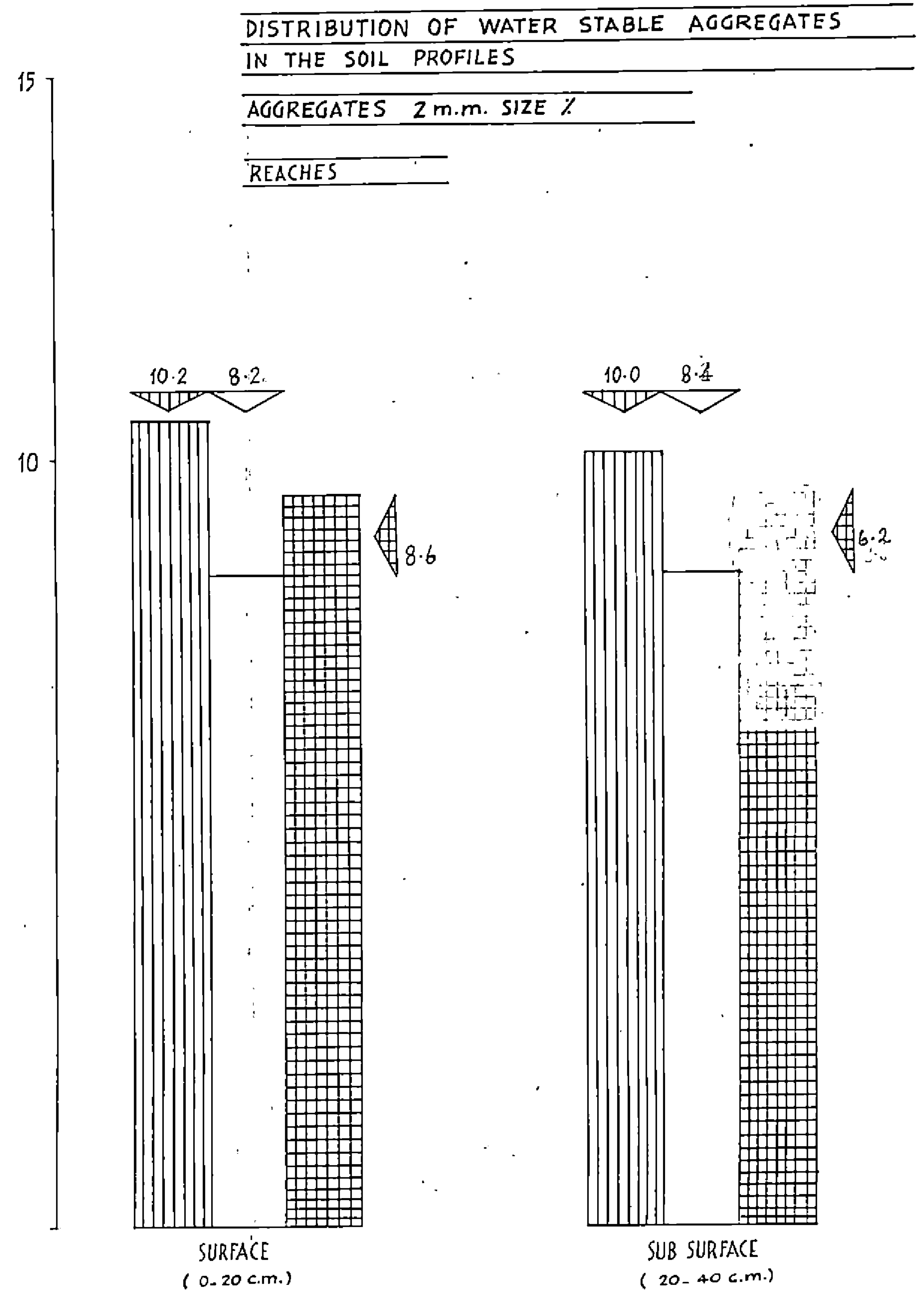


FIG. 7

Table 4b. Aggregate analysis of soil - particles 2 mm size (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	5.0	2.0	4.0	7.4	8.8	10.0
2	Kallayam	10.0	9.0	3.0	4.0	9.2	21.0
3	Kulathupuzha	12.0	13.0	8.0	6.6	12.6	7.2
4	Neyyattinkara	22.0	9.0	8.6	8.4	7.0	8.8
5	Ottasekharamangalam	14.8	4.0	12.0	8.4	10.8	9.0
6	Palode	6.4	6.0	11.4	7.2	8.0	8.8
7	Punalur	6.6	9.4	4.8	3.4	12.0	11.0
8	Thalavur	6.6	5.2	16.4	10.4	10.0	10.0
9	Uzhamalakkal	6.0	4.0	8.0	16.0	12.0	9.0
10	Vellarada	6.0	4.0	7.0	8.0	8.0	8.0
11	Vembayam	6.6	6.0	8.6	14.0	7.4	8.0
12	Vithura	2.2	3.0	6.0	7.2	16.0	9.6
	Mean	8.6	6.2	8.2	8.4	10.2	10.0

CD between soils x depth = 5.3
" " reaches x depth = 2.6
" " soils x reaches = 6.5



DISTRIBUTION OF WATER STABLE AGGREGATES IN THE SOIL PROFILES
AGGREGATES 2 m.m. SIZE %
REACHES
15
10
10·2
8·2
8·6
10·0
8·4
6·2
SURFACE
(0-20 c.m.)
SUB SURFACE
(20-40 c.m.)

FIG. 8

of such aggregates in the soils located at the three reaches. The maximum value was registered in the surface soils of the lower reaches of Neyyattinkara and the minimum 2 percent in the Anchal soil of the lower reaches at a depth of 20 to 40 cm.

c. Particles of 1 mm size

The 1 mm sized particles showed a marked difference due to locational effect, which ranged from 4.4 to 40.0 percent. The maximum value of 40.0 percent was registered in the middle reaches of Vembayam in the surface soil (0 to 20 cm) (Table 4c).

Significant difference in the content of 1 mm sized particle was also observed due to the interaction effect of soils and depth.

d. Particles of 0.5 mm size

The content of 0.5 mm sized particles in the different locations varied from 6.2 to 40.0 percent and it was significantly higher in the lower reaches when compared to the corresponding middle and upper reaches (Table 4d).

Table 4c. Aggregate analysis of soils - particles 1 mm size (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	13.4	8.0	12.0	10.0	6.8	8.0
2	Kallayam	18.0	21.2	20.0	23.2	18.0	27.4
3	Kulathupuzha	20.0	27.8	24.6	14.0	17.0	8.4
4	Neyyattinkara	19.0	16.0	12.0	22.0	12.0	10.2
5	Ottasekharamangalam	30.0	10.8	9.0	13.6	16.0	18.0
6	Palode	24.0	28.0	28.0	10.0	10.6	8.0
7	Punalur	19.0	20.8	12.0	4.4	18.6	18.0
8	Thalavur	31.4	30.0	16.0	11.2	14.0	12.0
9	Uzhamalakkal	18.0	31.0	18.2	13.4	16.0	8.0
10	Vellarada	14.0	14.0	6.0	10.0	14.0	7.0
11	Vembayam	24.8	22.0	40.0	34.0	16.0	28.8
12	Vithura	39.0	20.0	20.0	28.0	18.0	20.8
	Mean	22.6	20.8	18.2	16.2	14.8	14.6

CD between soils x slope = 11.2
" " reaches x depth = 5.6
" " soils x reaches = 13.7

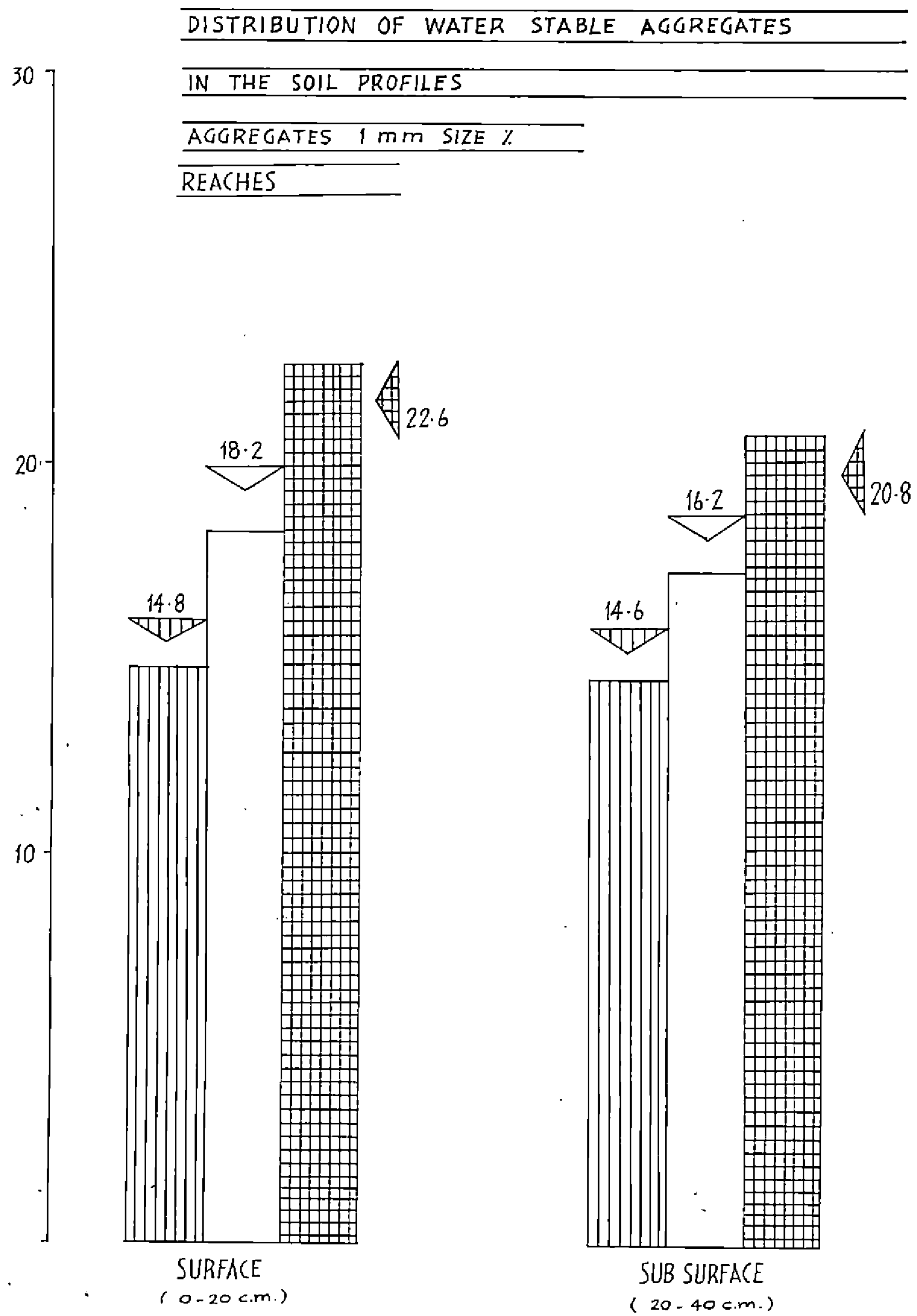

DISTRIBUTION OF WATER STABLE AGGREGATES
IN THE SOIL PROFILES
AGGREGATES 1 mm SIZE %
REACHES
30
20
10
14·8
18·2
22·6
14·6
16·2
20·8
SURFACE
(0-20 c.m.)
SUB SURFACE
(20-40 c.m.)

FIG. 9

Table 4d. Aggregate analysis of soils - particles 0.5 mm size (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	20.8	40.0	18.0	20.6	6.4	9.0
2	Kallayam	17.6	17.0	34.0	24.0	22.6	7.6
3	Kulathupuzha	16.0	12.0	11.6	13.4	8.0	8.8
4	Neyyattinkara	10.8	24.0	16.6	14.0	7.0	6.2
5	Ottasekharamangalam	21.2	24.4	10.2	10.8	6.4	12.0
6	Palode	20.8	26.0	16.0	16.0	20.4	10.0
7	Punalur	26.0	22.0	10.2	8.6	14.0	9.4
8	Thalavur	22.0	22.0	25.2	12.0	14.0	7.0
9	Uzhamalakkal	30.0	16.0	17.8	14.8	12.0	8.0
10	Vellarada	24.6	22.0	8.0	21.0	8.0	12.0
11	Vembayam	24.0	33.0	6.6	8.8	17.0	20.8
12	Vithura	22.6	28.0	20.0	16.0	14.4	24.0
	Mean	21.4	23.9	16.1	15.0	12.5	11.2

CD between soils x depth = 7.6

" " reaches x depth = 3.8

" " soils x reaches = 9.4

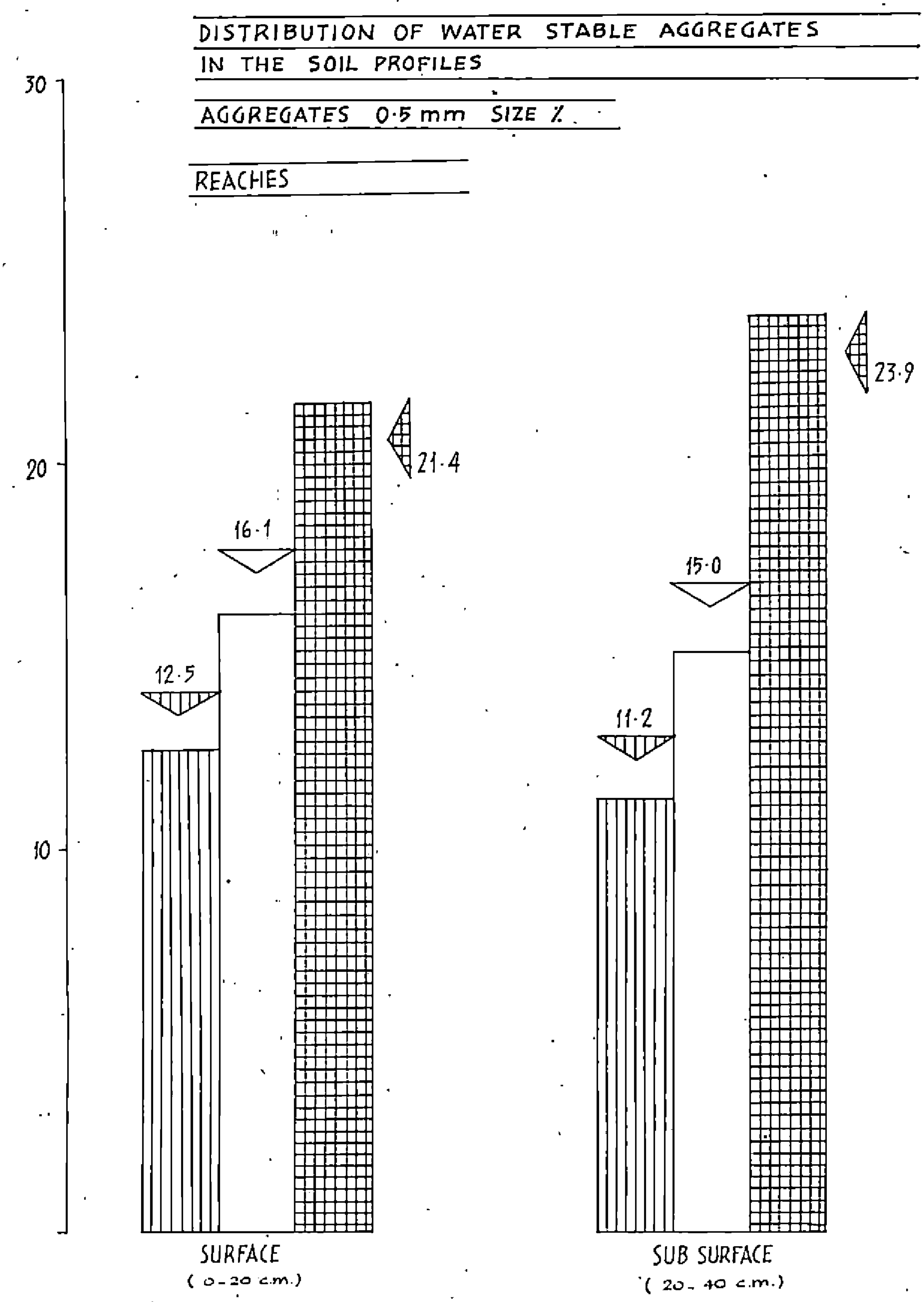

DISTRIBUTION OF WATER STABLE AGGREGATES
IN THE SOIL PROFILES
AGGREGATES 0·5 mm SIZE %
REACHES
30
20
10
12·5
16·1
21·4
11·2
15·0
23·9
SURFACE
(0-20 c.m.)
SUB SURFACE
(20-40 c.m.)

FIG. 10

All the three reaches showed significant difference in the content of these particles at various slopes. However, there was no difference due to the depth of the soil at different slopes.

e. Particles of 0.25 mm size

The particles of size 0.25 mm varied from 4.0 to 27.0 percent in the different locations (Table 4e).

Soils from Anchal recorded the highest value in the lower reaches and soils from Vembayam the least value in the middle reaches.

Though the 0.25 mm size particles were significantly higher in the lower reaches, there was much difference in their content between the middle reaches and upper reaches.

f. Particles of 0.1 mm size

There was appreciable difference in the content of 0.1 mm size particles in the samples from the different reaches in all the soils (Table 4f). The lowest value (2.6 percent) was recorded in the upper reaches of Thalavur soil, while the highest content of 19.0 percent was recorded in the lower reaches of Neyyattinkara soil.

Table 4e. Aggregate analysis of soils - particle 0.25 mm size (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	18.0	27.0	20.0	22.0	16.0	16.0
2	Kallayam	14.4	11.0	12.0	19.0	9.0	8.0
3	Kulathupuzha	10.0	12.0	12.0	12.0	6.0	10.2
4	Neyyattinkara	12.0	12.0	15.6	10.0	8.8	6.0
5	Ottasekharamangalam	13.6	19.2	12.8	4.8	6.8	7.6
6	Palode	25.4	14.0	9.2	8.6	9.0	6.8
7	Punalur	12.0	9.2	18.6	5.8	6.4	12.0
8	Thalavur	16.4	14.0	7.2	14.6	8.6	5.0
9	Uzhamalakkal	12.0	24.0	12.0	6.6	6.0	21.0
10	Vellarada	22.0	21.0	10.0	18.8	15.0	10.0
11	Vembayam	11.0	8.8	8.0	4.0	8.4	8.4
12	Vithura	12.0	17.0	10.0	12.0	11.6	14.4
	Mean	14.9	16.6	12.3	11.5	9.3	10.5

CD between soils x depth = 7.7
" " reaches x depth = 3.9
" " soils x reaches = 9.5

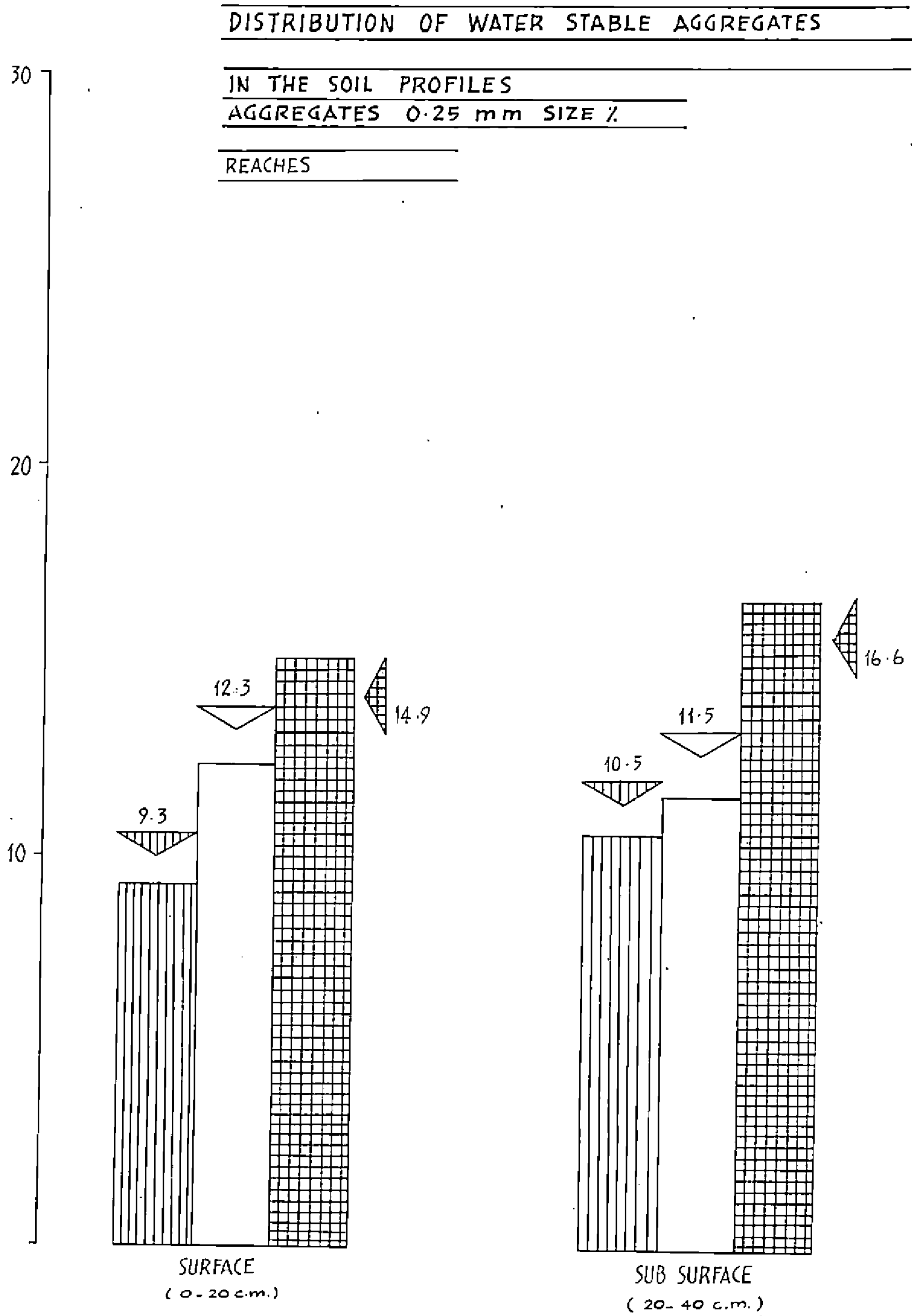

DISTRIBUTION OF WATER STABLE AGGREGATES
IN THE SOIL PROFILES
AGGREGATES 0·25 mm SIZE %
REACHES
30
20
10
9.3
12.3
14.9
10.5
11.5
16.6
SURFACE
(0-20 c.m.)
SUB SURFACE
(20- 40 c.m.)

FIG. 11

Table 4f. Aggregate analysis of soils - particles 0.1 mm size (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	18.0	12.0	12.0	11.0	6.0	7.0
2	Kallayam	8.0	11.0	14.6	15.4	5.4	6.2
3	Kulathupuzha	5.6	10.0	6.0	11.0	6.0	4.8
4	Neyyattinkara	6.8	19.0	16.4	6.4	7.4	6.2
5	Ottasekharamangalam	11.6	12.0	10.2	6.0	6.6	9.4
6	Palode	14.0	10.0	8.0	11.2	10.2	6.8
7	Punalur	12.0	14.0	10.6	10.0	6.0	8.0
8	Thalavur	9.0	10.0	4.6	8.0	2.6	6.0
9	Uzhamalakkal	12.0	14.0	8.0	7.0	4.0	14.0
10	Vellarada	15.0	10.0	6.0	20.0	11.0	8.0
11	Vembayam	6.0	7.0	6.0	8.0	8.0	8.0
12	Vithura	10.0	12.0	6.0	4.0	5.0	8.0
	Mean	10.7	11.8	9.0	9.8	6.5	7.7

CD between soils x depth = 6.6

" " reaches x depth = 3.3

" " soils x reaches = 8.1

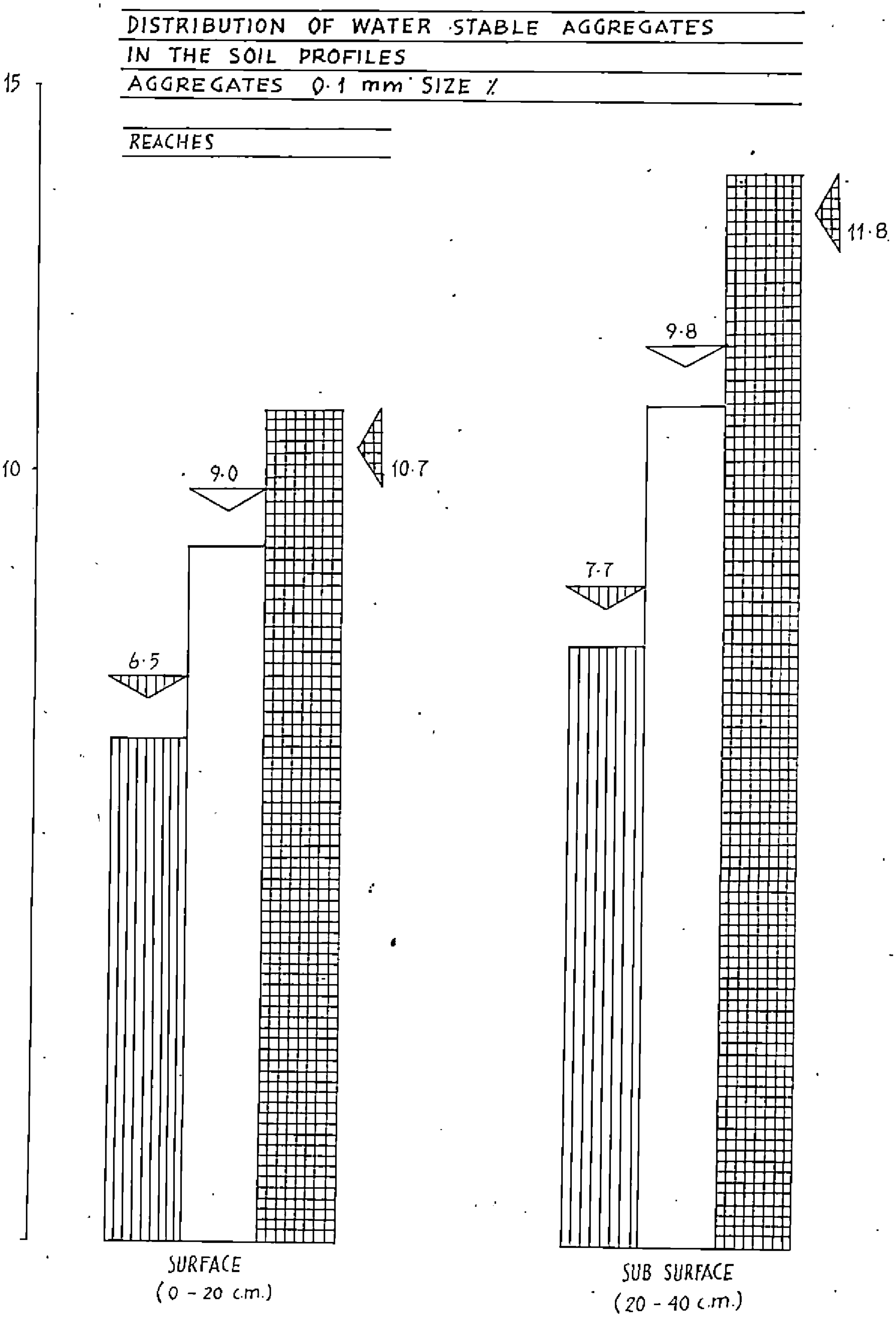

DISTRIBUTION OF WATER STABLE AGGREGATES
IN THE SOIL PROFILES
AGGREGATES 0·1 mm SIZE %
REACHES
15
10
6·5
9·0
10·7
7·7
9·8
11·8
SURFACE
(0 - 20 c.m.)
SUB SURFACE
(20 - 40 c.m.)

FIG. 12

g. Particles <0.1 mm size

It may be seen from Table 4g that the particle size of 0.1 mm size was significantly higher in the lower reaches and the highest value of 19.4 percent was registered in the lower reaches of Ottasekharamangalam, while the lowest value of 0.4 percent in the upper reaches of Kulathupuzha.

Highly significant differences existed among the three slopes in the content of these aggregates. It was significantly high in the lower reaches and low in the upper reaches of all soils.

B. CHEMICAL PROPERTIES

pH

Soil pH in the different locations varied from 3.8 to 5.5. The lowest pH of 3.8 was registered in the surface soils of the middle reaches of Kallayam, and the highest pH (5.5) was registered in the surface soil of the upper reaches of soils at Vellarada (Table 5a).

Though there was no significant difference between the three reaches of the different locations, pH was found

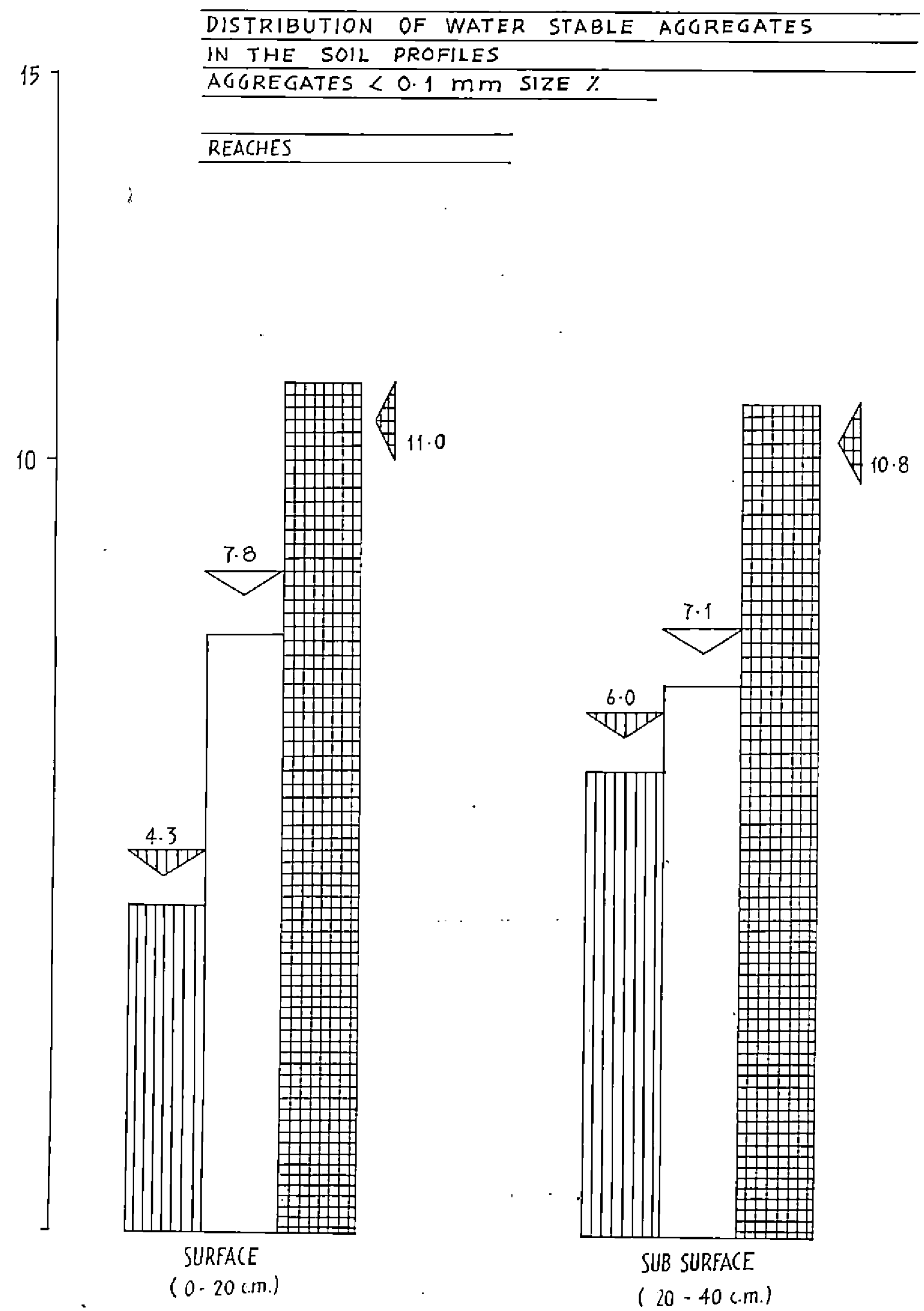
Table 4g. Aggregate analysis of soil - particles < 0.1 mm size (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	17.8	10.0	10.0	9.0	1.6	7.2
2	Kallayam	9.2	10.8	14.4	12.4	10.2	9.2
3	Kulathupuzha	16.4	4.2	9.0	7.0	0.4	1.8
4	Neyyattinkara	15.4	18.0	4.8	3.2	3.8	3.8
5	Ottasekharamangalam	6.6	19.4	11.8	10.4	1.4	10.0
6	Palode	6.6	7.0	1.4	5.0	5.4	5.6
7	Punalur	8.8	11.6	7.2	0.8	1.0	4.8
8	Thalavur	9.6	7.4	8.0	7.8	4.6	6.0
9	Uzhamalakkal	8.0	6.4	4.0	3.4	2.0	5.0
10	Vellarada	10.4	14.0	5.0	10.2	12.0	7.0
11	Vembayam	11.0	11.2	10.8	9.2	7.2	6.0
12	Vithura	12.2	9.0	8.0	6.8	3.0	6.0
	Mean	11.0	10.8	7.8	7.1	4.3	6.0

CD between soils x depth = 5.4

" " reaches x depth = 2.7

" " soils x reaches = 6.6



DISTRIBUTION OF WATER STABLE AGGREGATES
IN THE SOIL PROFILES
AGGREGATES < 0·1 mm SIZE %
REACHES
15
10
4·3
7·8
11·0
6·0
7·1
10·8
SURFACE
(0 - 20 c.m.)
SUB SURFACE
(20 - 40 c.m.)

FIG. 13

Table 5a. Chemical properties of soils - pH.

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	4.7	4.6	4.4	4.3	4.6	4.5
2	Kallayam	4.7	4.6	3.8	4.4	4.9	4.6
3	Kulathupuzha	5.0	5.0	4.8	4.9	5.4	5.4
4	Neyyattinkara	4.3	4.7	5.1	4.9	5.1	5.0
5	Ottasekharamangalam	4.0	4.2	4.7	4.6	4.5	4.4
6	Palode	4.7	4.9	4.6	4.5	4.7	4.4
7	Punalur	4.6	4.7	4.9	4.6	4.8	4.7
8	Thalavur	4.5	4.2	5.1	4.6	4.5	4.1
9	Uzhamalakkal	4.8	4.6	4.9	4.7	4.4	4.4
10	Vellarada	4.6	4.4	4.6	4.4	5.5	5.4
11	Vembayam	4.2	4.2	4.9	5.0	4.5	4.6
12	Vithura	4.4	4.6	4.6	4.5	4.5	4.4
	Mean	4.5	4.5	4.7	4.6	4.7	4.6

CD between soils x depth = 0.2
" " reaches x depth = 0.1
" " soils x reaches = 0.2

SOIL pH IN PROFILES

REACHES

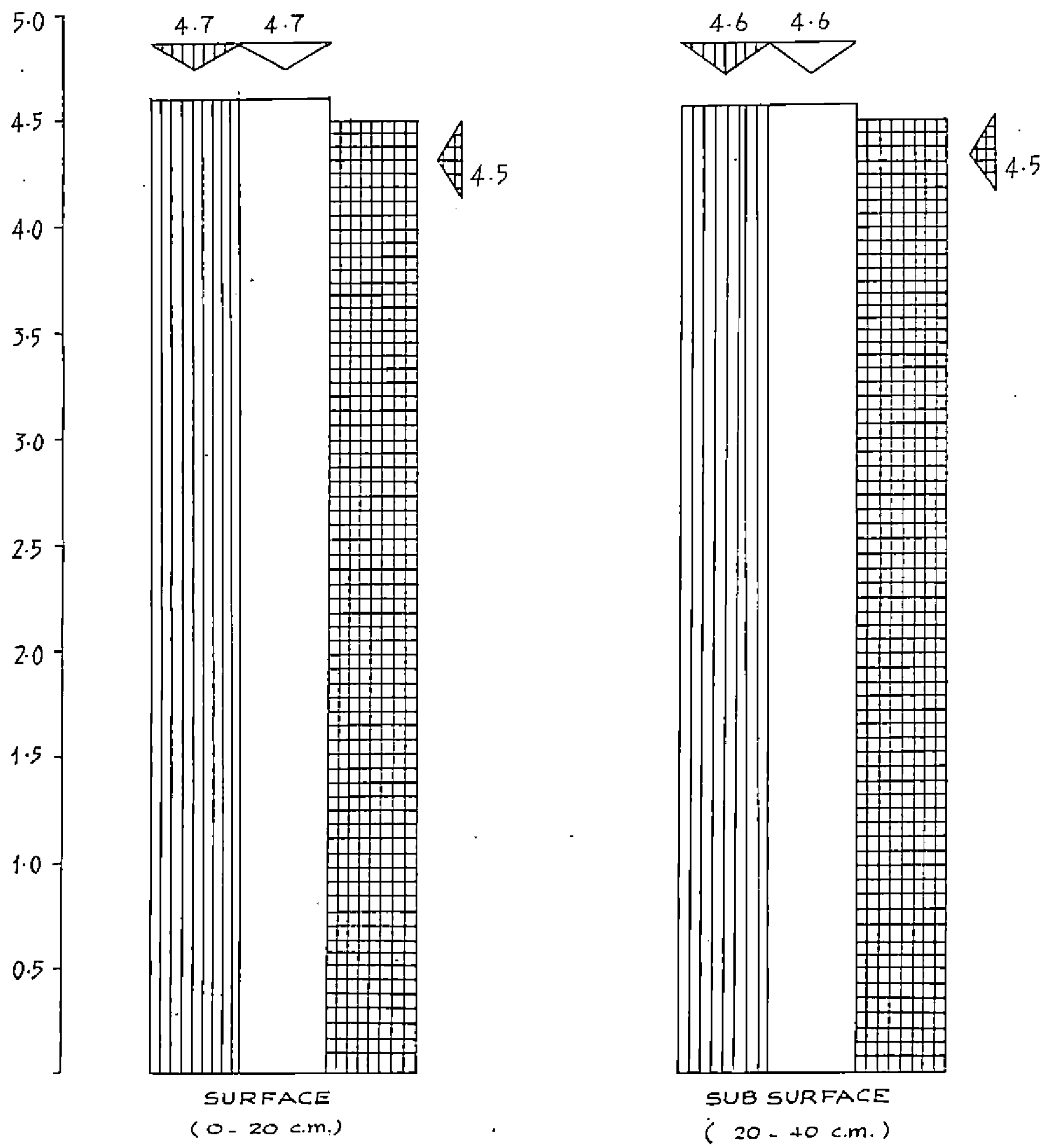


FIG. 14

to be generally lower in the lower reaches of the various soils.

Organic matter

The organic matter content of the soils showed a marked difference due to location effect and it ranged from 0.46 to 5.37 percent. The maximum organic matter content of 5.37 percent was registered in the lower reaches of the surface soil of Neyyattinkara (Table 5b). Lower reaches of Palode registered the least content of 0.464 percent at 20 to 40 cm depth.

A significant difference in the organic matter content was observed due to the interaction effect of soils and depth. The accumulation was maximum in the surface soils compared to the sub surface ones.

A marked difference was also noticed due to the effect of slope at various locations.

C/N ratio

The C/N ratio as seen from Table 5c varied from 4.76 in the upper reaches of Vembayam to 38.09 in the middle reaches of Punalur soils.

Table 5b. Chemical properties of soils - Organic matter content (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	1.81	0.87	1.96	1.44	1.29	1.75
2	Kallayam	2.89	2.67	3.62	3.51	3.72	2.68
3	Kulathupuzha	4.13	3.10	1.49	1.55	2.34	1.81
4	Neyyattinkara	5.37	3.31	3.87	2.58	3.41	4.03
5	Ottasekharamangalam	2.84	1.91	0.87	0.77	0.98	0.82
6	Palode	1.86	0.46	1.08	1.34	0.72	0.72
7	Punalur	3.10	2.84	1.49	1.24	2.65	2.06
8	Thalavur	2.48	1.89	2.06	1.18	2.48	1.29
9	Uzhamalakkal	2.68	0.93	2.32	1.75	1.96	1.81
10	Vellarada	2.79	1.86	1.49	0.67	1.70	1.34
11	Vembayam	3.77	3.56	1.70	1.49	1.75	0.93
12	Vithura	2.74	2.37	2.37	3.25	2.94	0.77
	Mean	3.03	2.14	2.02	1.73	2.20	1.66

CD between soils x depth = 0.91
" " reaches x depth = 0.45
" " soils x reaches = 1.11

ORGANIC MATTER CONTENT IN THE SOIL PROFILES %

REACHES

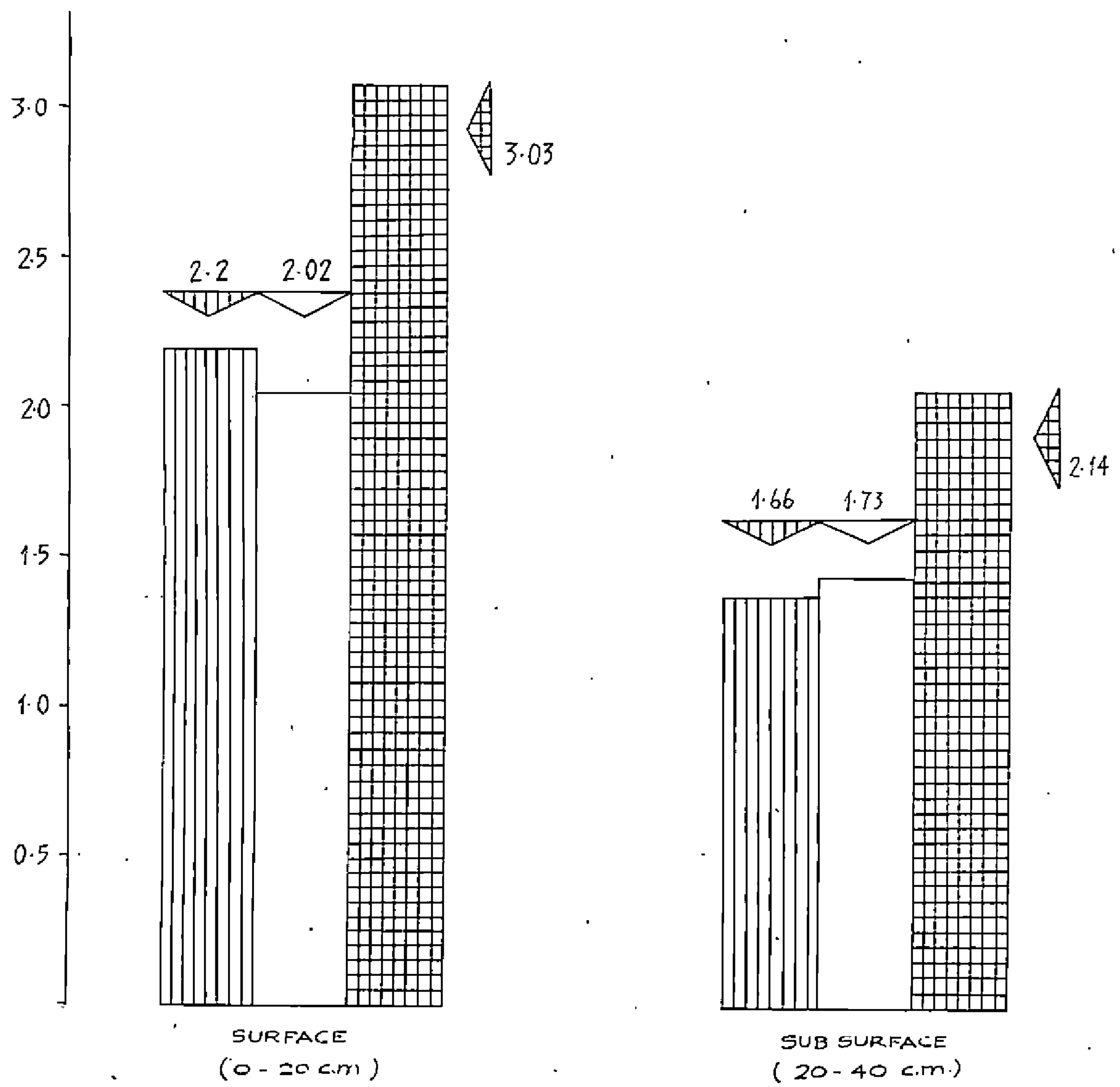


FIG. 15

Table 5c. Chemical properties of soils - C/N ratio.

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	13.88	26.90	20.10	22.20	13.22	17.98
2	Kallayam	14.81	16.40	22.22	21.58	19.04	16.50
3	Kulathupuzha	18.41	11.90	9.20	11.90	12.47	9.25
4	Neyyattinkara	20.60	25.39	29.76	15.80	34.90	20.60
5	Ottasekharamangalam	10.90	19.50	8.99	7.93	10.05	8.46
6	Palode	19.04	14.28	11.11	13.75	11.11	11.11
7	Punalur	13.60	17.46	23.01	38.09	20.23	21.16
8	Thalavur	15.23	19.40	15.87	18.25	32.80	13.22
9	Uzhamalakkal	13.75	14.28	23.80	26.98	20.10	18.51
10	Vellarada	12.24	14.28	15.34	10.31	17.46	20.63
11	Vembayam	19.31	15.64	17.46	11.50	17.98	4.76
12	Vithura	21.03	36.50	24.33	33.33	22.61	20.37
	Mean	10.04	19.32	18.43	19.30	19.33	15.21

CD between soils x depth = 7.34

" " reaches x depth = 3.67

" " soils x reaches = 8.99

C/N RATIO IN THE SOIL PROFILES

REACHES

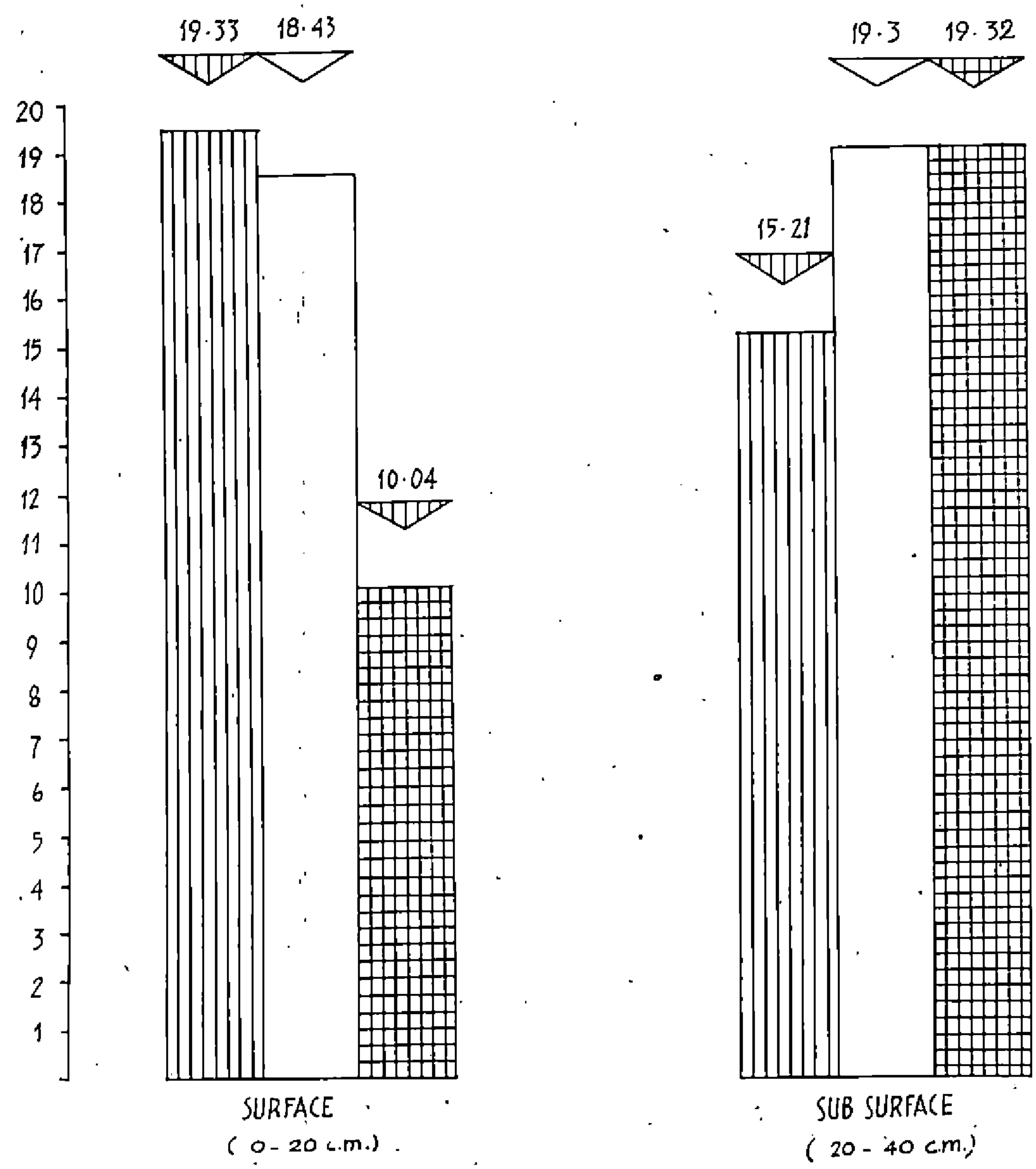


FIG. 16

There was significant difference in the ratio between different reaches and within reaches.

Total Nitrogen

The total nitrogen content of the different locations varied from 0.018 to 0.151 percent (Table 5d).

Generally, the surface soils contained a comparatively higher amount of total nitrogen than the sub surface soils in most of the locations.

Available Nitrogen

The available nitrogen was comparatively higher in the middle and upper reaches than in the corresponding lower reaches (Table 5e).

The surface soil in the middle reaches of Vembayam registered the maximum value (298 kg/ha) for available nitrogen,while the sub surface soil of the middle reaches of Uzhamalakkal recorded the lowest value (100 kg/ha).

A significant difference in the available nitrogen content was observed between the soils at different depths. It was significantly higher in the surface soils in almost all the locations.

Table 5d. Chemical properties of soils - Total nitrogen (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	0.075	0.018	0.056	0.037	0.056	0.056
2	Kallayam	0.113	0.094	0.094	0.094	0.113	0.094
3	Kulathupuzha	0.132	0.151	0.094	0.075	0.132	0.113
4	Neyyattinkara	0.151	0.075	0.075	0.094	0.056	0.113
5	Ottasekharamangalam	0.151	0.056	0.056	0.056	0.056	0.056
6	Palode	0.056	0.018	0.056	0.056	0.037	0.037
7	Punalur	0.132	0.094	0.037	0.018	0.075	0.056
8	Thalavur	0.094	0.056	0.075	0.037	0.075	0.056
9	Uzhamalakkal	0.113	0.037	0.056	0.037	0.056	0.056
10	Vellarada	0.132	0.075	0.056	0.037	0.056	0.037
11	Vembayam	0.113	0.132	0.056	0.075	0.056	0.113
12	Vithura	0.075	0.037	0.056	0.056	0.075	0.037
	Mean	0.111	0.070	0.064	0.056	0.070	0.097

CD between soils x depth = 0.074

" " reaches x depth = 0.036

" " soils x reaches = 0.090

Table 5e. Chemical properties of soils - Available nitrogen (kg/ha).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	210	164	188	208	239	245
2	Kallayam	204	155	192	208	247	231
3	Kulathupuzha	255	194	210	208	217	194
4	Neyyattinkara	218	274	178	172	162	166
5	Ottasekharamangalam	213	170	159	151	186	204
6	Palode	131	192	151	174	110	149
7	Punalur	212	208	131	141	184	184
8	Thalavur	206	155	245	240	247	208
9	Uzhamalakkal	210	133	182	100	186	162
10	Vellarada	215	229	255	170	180	174
11	Vembayam	155	161	298	168	181	221
12	Vithura	162	162	168	200	219	206
	Mean	199	183	196	178	196	195

CD between soils x depth = 48

" " reaches x depth = 24

" " soils x reaches = 59

DISTRIBUTION OF AVAILABLE NITROGEN IN THE SOIL PROFILES (kg/ha)

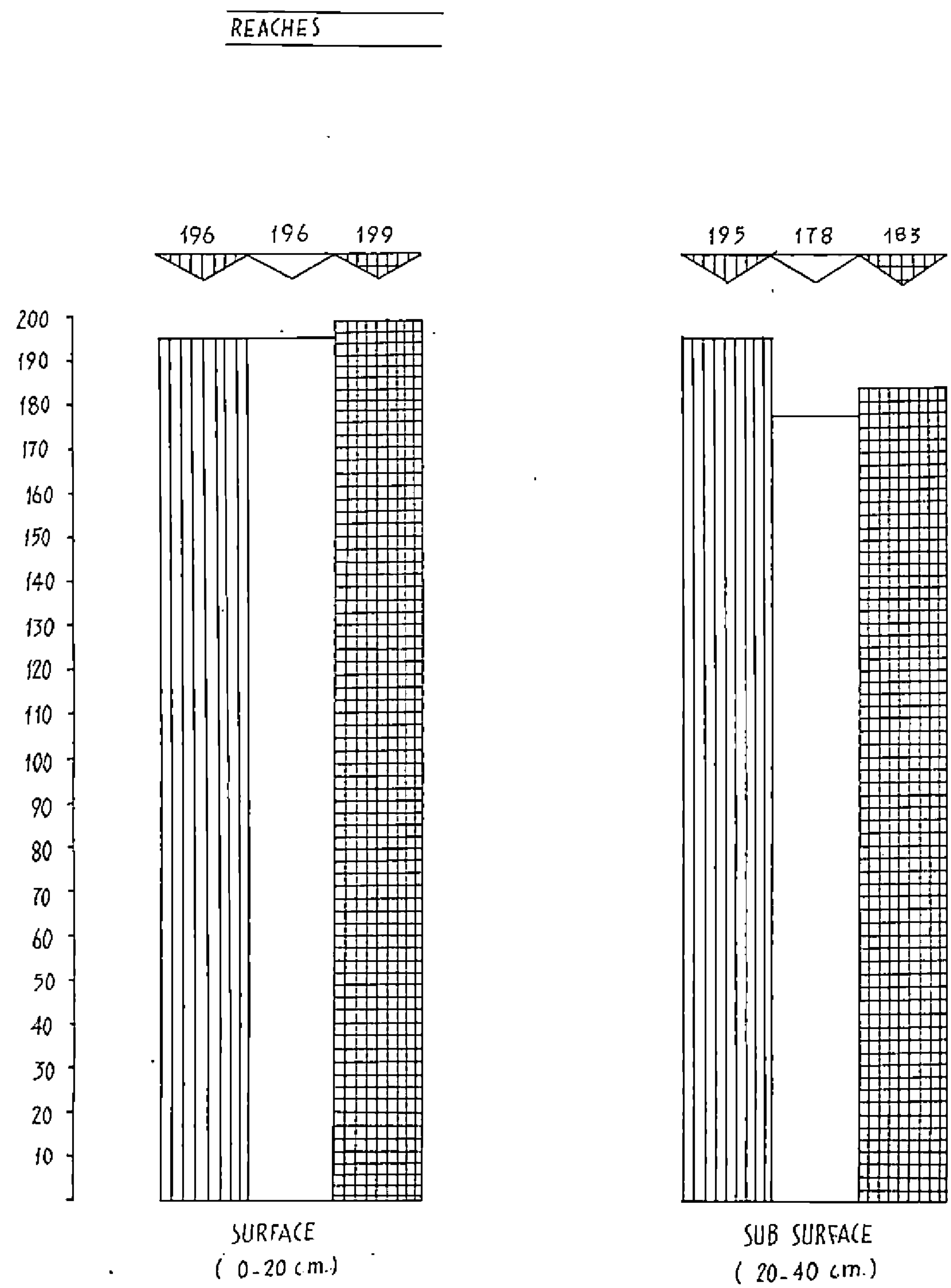


FIG. 17

Total phosphorus

The total phosphorus content in the different soil samples varied from 0.016 percent in the surface soils of the lower reaches in Kallayam to 0.094 percent in the surface soils of the middle reaches in Palode (Table 5f). Total phosphorus was significantly higher in the middle reaches than in the lower and upper reaches. In the lower reaches it was very low.

Not much variation in the content of total phosphorus was noticed for the samples located at the two depths in the different soils.

Available phosphorus

Available phosphorus was invariably higher in the lower and middle reaches than in the upper reaches (Table 5g). It was significantly higher in the surface horizons than in the lower horizons. Maximum available phosphorus content of 94 kg/ha could be recorded in the surface soils of the lower reaches in Palode and lowest content of 28 kg/ha could be noted in the middle reaches of Kallayam and Uzhamalakkal in the sub surface region.

Table 5f. Chemical properties of soils - Total phosphorus (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	0.028	0.065	0.056	0.049	0.045	0.032
2	Kallayam	0.016	0.020	0.028	0.024	0.045	0.051
3	Kulathupuzha	0.028	0.024	0.045	0.036	0.053	0.028
4	Neyyattinkara	0.045	0.041	0.086	0.057	0.041	0.045
5	Ottasekharamangalam	0.028	0.049	0.061	0.041	0.041	0.041
6	Palode	0.073	0.049	0.094	0.057	0.036	0.023
7	Punalur	0.053	0.024	0.057	0.045	0.053	0.036
8	Thalavur	0.028	0.086	0.041	0.053	0.045	0.069
9	Uzhamalakkal	0.049	0.049	0.053	0.090	0.082	0.092
10	Vellarada	0.049	0.065	0.094	0.061	0.091	0.090
11	Vembayam	0.036	0.032	0.082	0.065	0.036	0.092
12	Vithura	0.077	0.061	0.053	0.057	0.057	0.061
	Mean	0.043	0.047	0.062	0.053	0.052	0.055

CD between soils x depth = 0.023

" " reaches x depth = 0.011

" " soils x reaches = 0.028

Table 5g. Chemical properties of soils - Available phosphorus (kg/ha).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	67	78	67	58	54	38
2	Kallayam	38	29	33	28	54	54
3	Kulathupuzha	53	48	90	72	63	34
4	Neyyattinkara	54	49	86	68	49	54
5	Ottasekharamangalam	56	58	61	49	49	41
6	Palode	94	57	36	29	53	29
7	Punalur	57	45	53	36	36	29
8	Thalavur	86	41	53	45	69	49
9	Uzhamalakkal	58	49	63	28	82	33
10	Vellarada	49	65	90	61	90	68
11	Vembayam	72	64	82	65	65	36
12	Vithura	92	70	61	53	57	61
	Mean	65	54	65	49	60	43

CD between soils x depth = 18
" " reaches x depth = 8
" " soils x reaches = 21

DISTRIBUTION OF AVAILABLE PHOSPHORUS IN THE SOIL PROFILES (kg./ha)

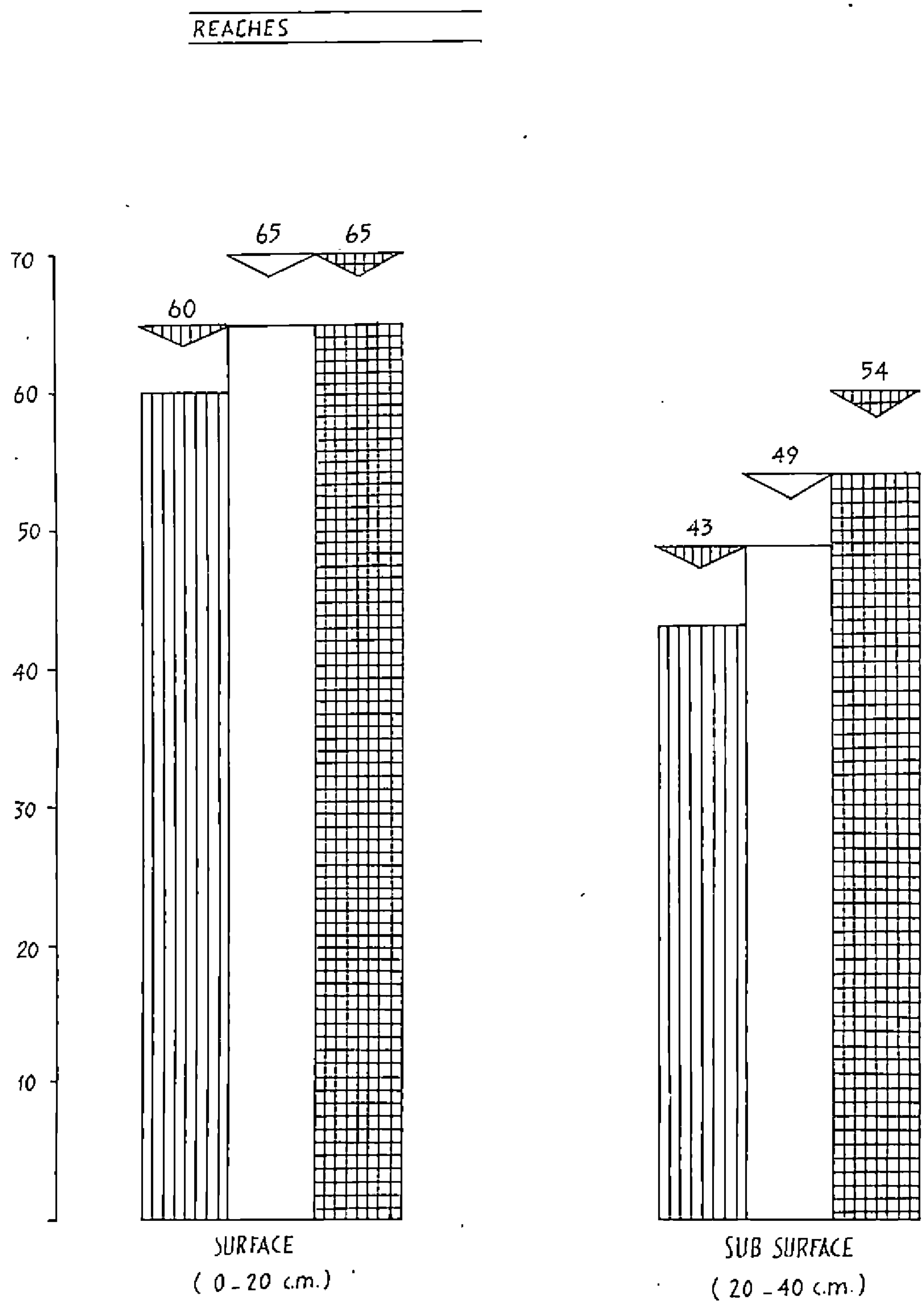


FIG. 18

The distribution of available phosphorus was significantly related to depth in all the soils.

Total potassium

The content of total potassium was significantly higher in the upper reaches when compared to other positions (Table 5h).

It ranged from the lowest value of 0.012 percent in the middle reaches of Uzhamalakkal to the highest value of 0.092 percent in the upper reaches of Kulathupuzha. Total potassium was higher in the surface soils than in the sub surface soils.

Exchangeable potassium

Exchangeable potassium content was higher in the lower than in the upper and middle reaches in all the locations. It varied from the lowest value of 148 kg/ha in the upper reaches of Vellarada to the highest value of 460 kg/ha in the lower reaches of Vembayam (Table 5i).

There was significant difference in the content of available potassium at the two depths, the surface

Table 5h. Chemical properties of soils - Total potassium (percent).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	0.048	0.020	0.044	0.024	0.068	0.032
2	Kallayam	0.038	0.028	0.028	0.038	0.072	0.070
3	Kulathupuzha	0.042	0.028	0.044	0.040	0.092	0.084
4	Neyyattinkara	0.038	0.054	0.048	0.044	0.048	0.040
5	Ottasekharamangalam	0.024	0.028	0.064	0.030	0.082	0.072
6	Palode	0.036	0.014	0.044	0.040	0.026	0.028
7	Punalur	0.060	0.056	0.052	0.056	0.056	0.032
8	Thalavur	0.036	0.032	0.048	0.030	0.050	0.034
9	Uzhamalakkal	0.054	0.034	0.022	0.012	0.044	0.048
10	Vellarada	0.044	0.066	0.064	0.036	0.024	0.019
11	Vembayam	0.080	0.068	0.040	0.034	0.044	0.032
12	Vithura	0.024	0.020	0.042	0.028	0.040	0.042
	Mean	0.043	0.037	0.045	0.034	0.053	0.044

CD between soils x depth = 0.015
" " reaches x depth = 0.079
" " soils x reaches = 0.019

Table 51. Chemical properties of soils - Exchangeable potassium (kg/ha).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	224	198	297	205	320	180
2	Kallayam	206	172	198	236	350	260
3	Kulathupuzha	318	180	298	280	298	290
4	Neyyattinkara	300	360	320	288	310	238
5	Ottasekharamangalam	260	280	310	242	340	280
6	Palode	320	160	280	260	228	202
7	Punalur	410	428	318	324	302	270
8	Thalavur	310	300	305	298	252	240
9	Uzhamalakkal	370	320	202	152	320	208
10	Vellarada	400	380	360	310	160	148
11	Vembayam	460	360	410	300	285	260
12	Vithura	280	180	312	270	292	280
	Mean	321	276	300	263	288	288

CD between soils x depth = 64

" " reaches x depth = 32

" " soils x reaches = 79

DISTRIBUTION OF AVAILABLE POTASSIUM IN THE SOIL PROFILES (kg/ha)

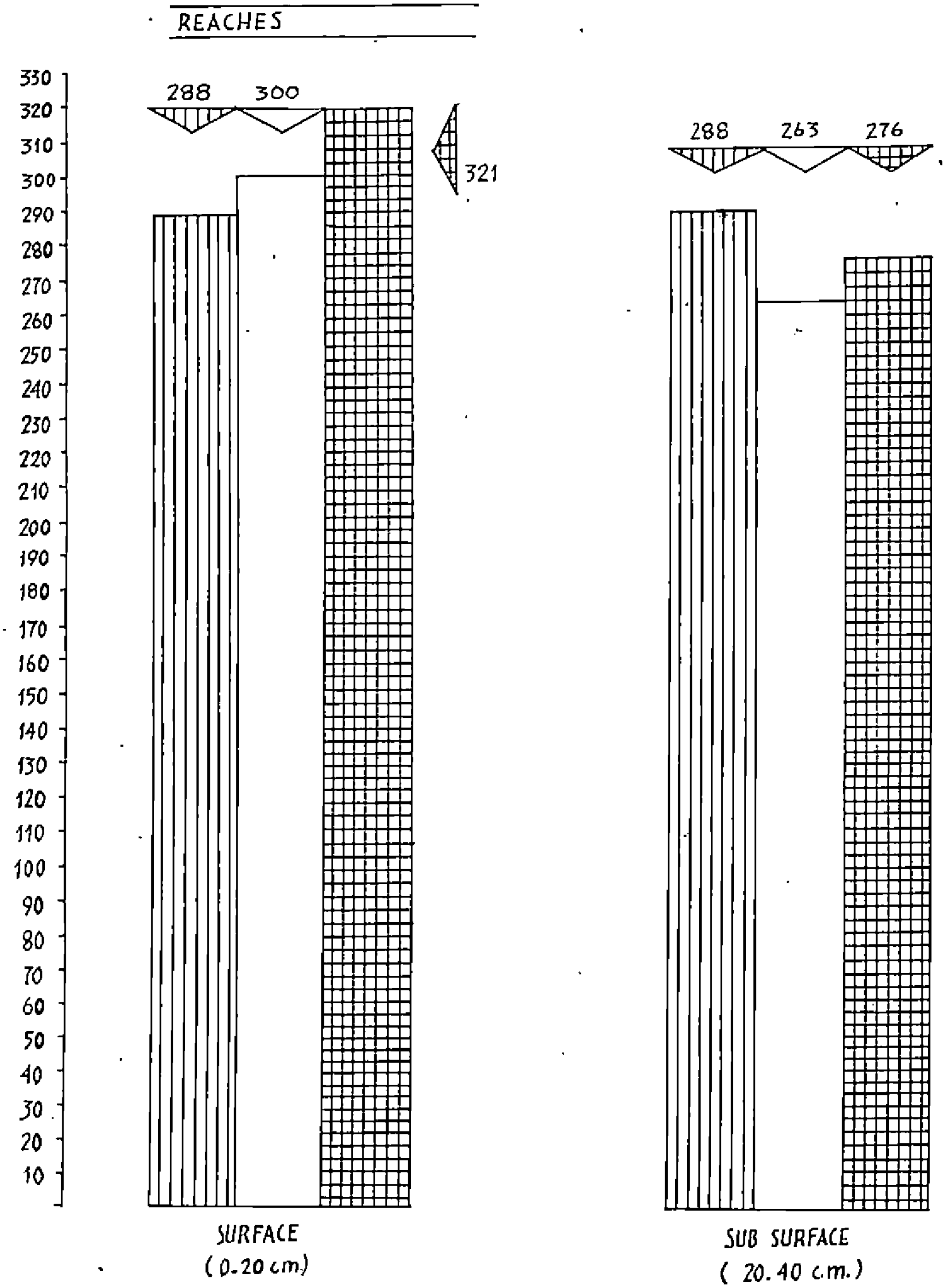


FIG. 19

soils generally recording a higher value than the corresponding sub surface soils.

Total calcium

The distribution of calcium in the various locations ranged from 5 me in the middle reaches of Uzhamalakkal to 19 me/100 g soil in the lower reaches of the soils of Vellarada (Table 5j).

Highly significant difference existed between the content of total calcium in the three slopes. In the lower reaches, total calcium showed the highest content and the upper reaches the lowest.

There was also significant difference between the two depths. Total calcium was much higher at a depth of 20 to 40 cm than at a depth of 0 to 20 cm.

Exchangeable calcium

Exchangeable calcium in the different locations varied from 0.6 me in the upper reaches of Kulathupuzha and Ottasekharamangalam to 2.00 me/100 g soil in the lower reaches of Kallayam. There was significant difference between the content of exchangeable calcium at the

Table 5j. Chemical properties of soils - Total calcium (me/100 g soil).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	11.0	14.0	5.4	12.9	7.5	11.0
2	Kallayam	14.0	18.5	10.5	14.5	9.0	12.0
3	Kulathupuzha	5.4	14.0	6.0	12.0	5.5	9.0
4	Neyyattinkara	11.5	14.8	8.5	13.0	5.5	10.6
5	Ottasekharamangalam	11.6	14.3	7.0	9.5	6.5	8.8
6	Palode	13.5	15.5	9.0	11.0	6.0	9.0
7	Punalur	11.6	14.8	7.4	11.0	5.5	9.0
8	Thalavur	11.5	14.5	6.0	9.3	5.5	8.5
9	Uzhamalakkal	6.2	9.5	5.0	9.3	5.5	8.0
10	Vellarada	12.3	19.0	10.0	18.6	8.0	11.0
11	Vembayam	11.0	15.5	9.0	9.9	6.0	7.3
12	Vithura	11.5	18.0	8.6	12.0	8.0	9.9
	Mean	10.9	15.2	7.7	11.9	6.5	9.5

CD between soils x depth = 1.8
" " reaches x depth = 0.9
" " soils x reaches = 2.2

DISTRIBUTION OF TOTAL CALCIUM
IN THE SOIL PROFILES (kg / ha)

REACHES

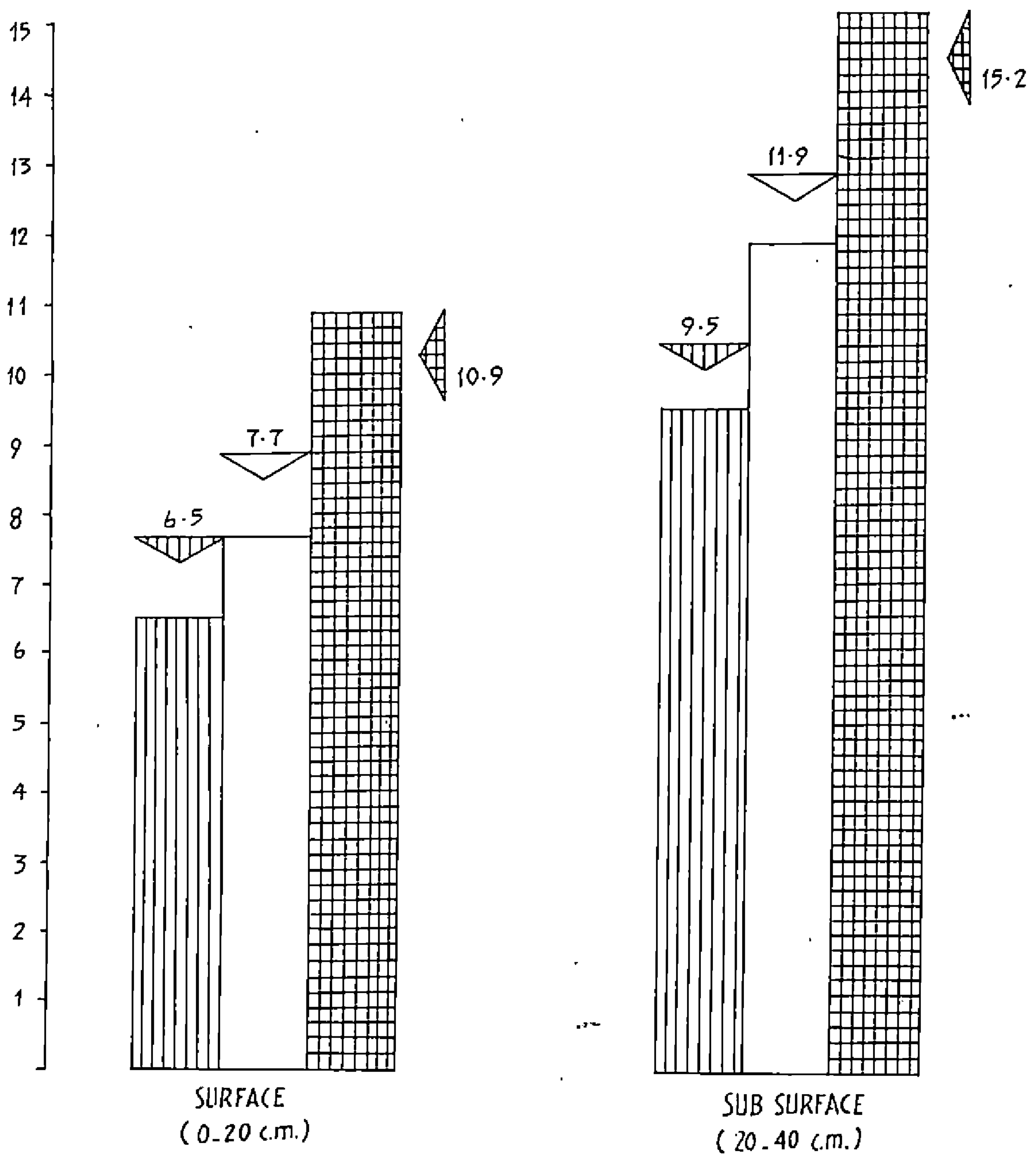


FIG. 20

three slopes. In the lower reaches it was significantly higher than in the upper reaches (Table 5k).

Significant difference could also be noted between the content of exchangeable calcium at the two depths. At 20 to 40 cm depth it was higher than in the soils at a depth of 0 to 20 cm.

Total magnesium

The total magnesium content in the soils varied from 9.33 me to 27.33 me/100 g soil. The maximum value of 27.33 me/100 g soil was observed in the lower depths (20 to 40 cm) of the lower reaches of Palode soil (Table 5l).

There was marked difference in the content of total magnesium at the two depths. At 20 to 40 cm depth it was significantly higher.

Slope of the soil did not have any influence on the distribution of total magnesium in the soils.

Exchangeable magnesium

The status of exchangeable magnesium in the different locations ranged from 1 to 3.3 me/100 g soil. The

Table 5k. Chemical properties of soils - Exchangeable calcium (me/100 g soil).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	0.64	1.63	0.60	1.20	0.81	1.05
2	Kallayam	1.60	2.05	1.30	1.06	1.05	1.40
3	Kulathupuzha	0.75	1.60	0.66	1.40	0.60	1.05
4	Neyyattinkara	0.90	1.64	1.06	1.43	0.64	1.28
5	Ottasekharamangalam	1.20	1.55	0.79	1.08	0.60	0.99
6	Palode	1.55	1.78	1.01	1.24	0.66	1.18
7	Punalur	1.28	1.55	0.84	1.28	0.74	1.02
8	Thalavur	1.30	1.55	0.69	1.13	0.68	0.99
9	Uzhamalakkal	0.71	1.14	0.68	1.03	0.69	0.93
10	Vellarada	1.41	1.96	1.08	1.95	0.91	1.20
11	Vembayam	1.28	1.90	1.05	1.18	0.71	0.84
12	Vithura	1.40	1.98	1.05	1.34	0.91	1.14
	Mean	1.17	1.69	0.90	1.28	0.75	1.09

CD between soils x depth = 0.25
" " reaches x depth = 0.12
" " soils x reaches = 0.31

DISTRIBUTION OF EXCHANGEABLE CALCIUM IN THE SOIL PROFILES (me / 100 g SOIL)

REACHES

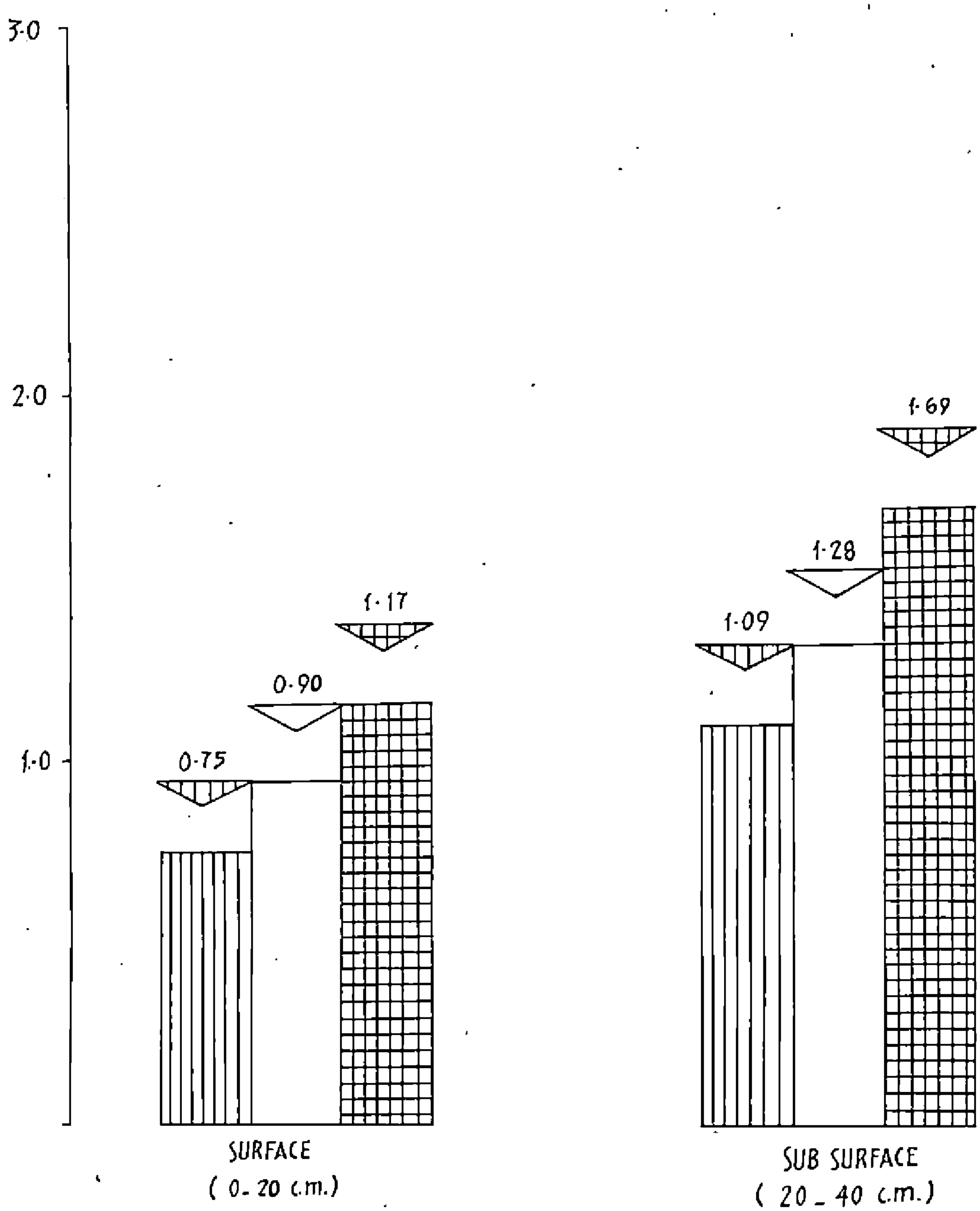


FIG. 21

Table 51. Chemical properties of soils - Total magnesium (me/100 g soil).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	23.35	23.68	15.96	18.43	12.08	17.50
2	Kallayam	26.66	25.10	16.68	20.10	15.80	21.76
3	Kulathupuzha	13.68	21.66	11.75	15.08	13.50	15.96
4	Neyyattinkara	23.41	26.66	16.63	19.26	11.75	20.50
5	Ottasekharamangalam	23.41	27.16	13.33	16.00	13.41	16.01
6	Palode	23.50	27.66	16.68	23.83	12.00	15.80
7	Punalur	20.08	23.83	14.16	17.58	11.00	15.08
8	Thalavur	24.16	26.75	14.33	16.81	13.41	20.15
9	Uzhamalakkal	15.34	21.83	10.25	14.66	9.33	13.41
10	Vellarada	20.10	24.30	14.28	21.66	10.08	15.75
11	Vembayam	20.08	25.83	11.75	16.40	10.05	15.83
12	Vithura	18.46	25.06	16.06	20.00	10.58	16.65
	Mean	21.02	24.96	14.32	18.32	11.92	17.03

CD between soils x depth = 2.58
" " reaches x depth = 0.95
" " soils x reaches = 3.16

DISTRIBUTION OF TOTAL MAGNESIUM IN THE SOIL PROFILES (me / 100 g SOIL)

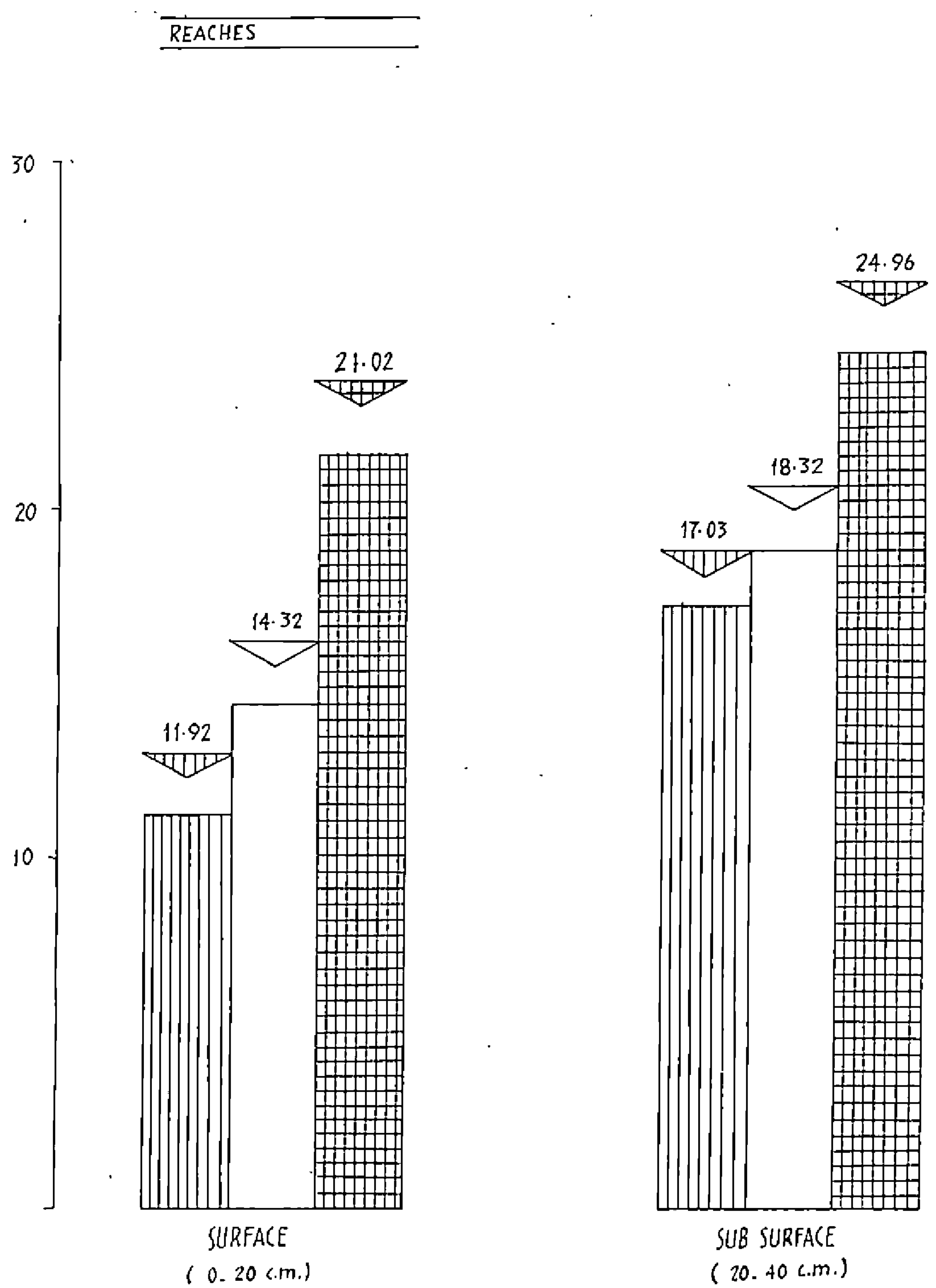


FIG. 22

maximum content was recorded in the lower reaches of Kallayam soil and the minimum in the upper reaches of Uzhamalakkal soils (Table 5m).

Highly significant differences existed between the three slopes in the distribution of exchangeable Mg. In the lower reaches it was significantly higher than the upper reaches where it was only very low.

There was also significant difference between the two depths. At 20 to 40 cm depth it was significantly higher than the corresponding surface soils at a depth of 0 to 20 cm.

Micronutrients

Total iron

Total iron content in the twelve locations varied from 20.72 me to 69.36 me/100 g soil, the highest value being recorded in the lower depth (20 to 40 cm) of the lower reaches of Vembayam soil and the lowest in the sub surface soils of the upper reaches at Kulathupuzha (Table 5n).

There was no significant difference between the

Table 5m. Chemical properties of soils - Exchangeable magnesium (me/100 g soil).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	2.51	2.63	1.67	2.0	1.38	1.98
2	Kallayam	3.0	3.30	1.76	2.23	1.75	2.40
3	Kulathupuzha	1.51	2.41	1.36	1.75	1.51	1.93
4	Neyyattinkara	2.46	2.83	1.96	2.30	1.33	2.01
5	Ottasekharamangalam	2.48	2.85	1.43	1.71	1.26	1.76
6	Palode	2.51	2.90	1.88	2.46	1.31	1.75
7	Punalur	2.13	2.58	1.60	1.90	1.21	1.68
8	Thalavur	2.58	2.85	1.55	1.85	1.46	2.15
9	Uzhamalakkal	1.75	2.35	1.15	1.55	1.03	1.46
10	Vellarada	1.93	2.43	1.50	2.26	1.09	1.75
11	Vembayam	2.16	2.73	1.26	1.81	1.06	1.71
12	Vithura	2.13	2.68	1.76	2.15	1.1	1.80
	Mean	2.26	2.72	1.57	2.0	1.29	1.87

CD between soils x depth = 0.18

" " reaches x depth = 0.09

" " soils x reaches = 0.22

DISTRIBUTION OF EXCHANGEABLE MAGNESIUM IN THE SOIL PROFILES (me / 100 g SOIL)

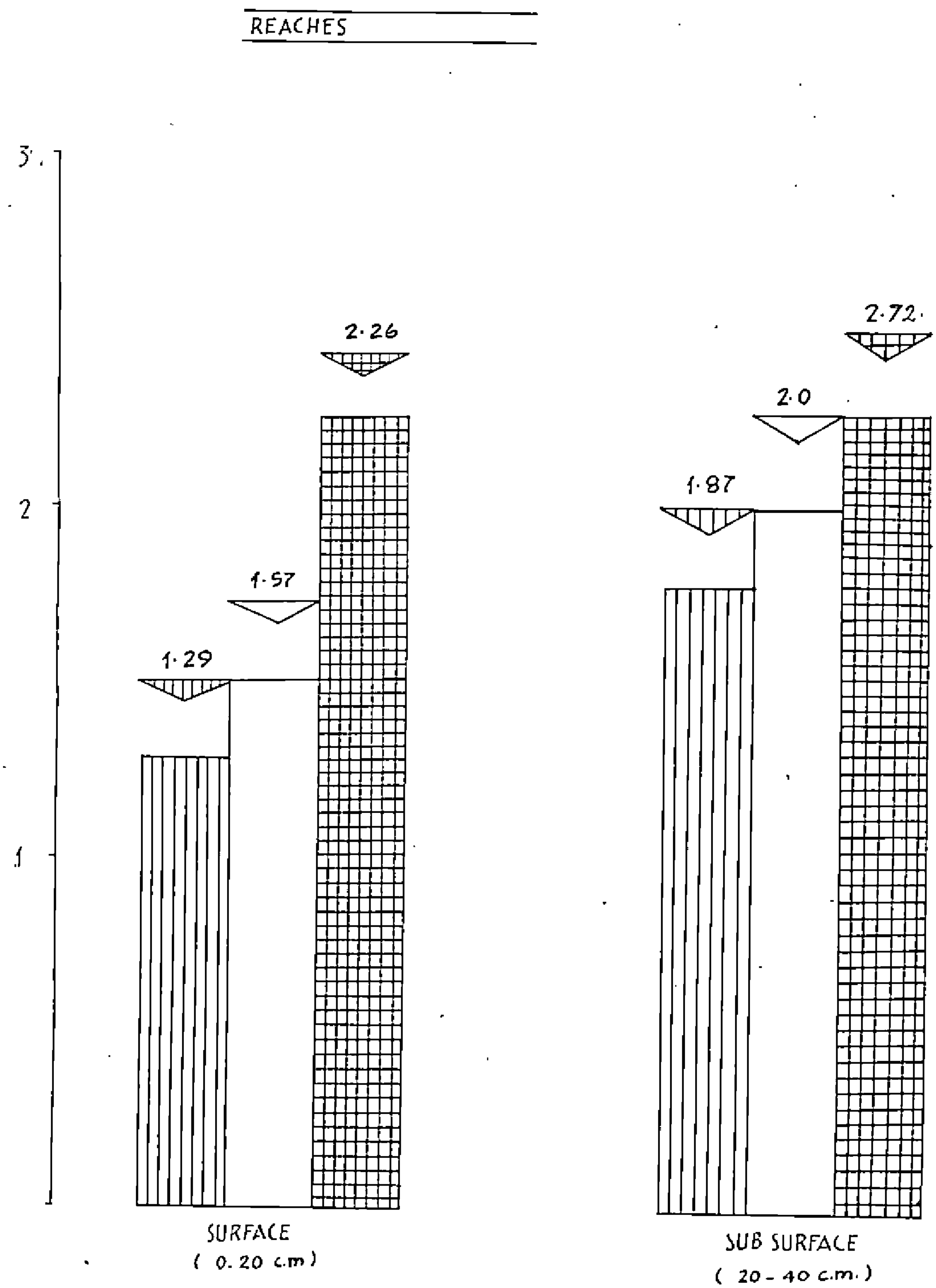


FIG. 23

Table 5n. Chemical properties of soils - Total iron (me/100 g soil).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	60.36	64.32	45.76	42.34	31.53	25.58
2	Kallayam	54.41	58.73	33.31	29.18	26.66	25.22
3	Kulathupuzha	50.63	56.93	39.27	33.51	28.04	20.72
4	Neyyattinkara	56.21	60.36	35.67	29.54	25.40	23.06
5	Ottasekharamangalam	57.83	62.34	44.14	39.81	35.31	26.12
6	Palode	54.77	58.55	42.88	34.95	36.21	31.71
7	Punalur	54.41	57.83	32.43	27.02	25.58	23.78
8	Thalavur	55.50	61.98	44.68	43.23	30.27	25.22
9	Uzhamalakkal	36.93	48.64	38.55	33.79	27.02	25.58
10	Vellarada	39.63	50.48	41.44	32.43	39.63	44.14
11	Vembayam	61.26	69.36	52.25	48.64	28.82	34.25
12	Vithura	57.65	63.06	41.44	33.33	36.93	29.54
	Mean	53.30	59.38	41.15	35.65	30.95	27.91

CD between soils x depth = 68.35

" " reaches x depth = 34.17

" " soils x reaches = 83.71

three reaches and also between the soils at two depths in the distribution of total iron.

Exchangeable iron

The exchangeable iron content in the different locations was very low and it registered a variation from 0.005 me to 0.056 me/100 g soil. The highest value was recorded in the lower reaches (0 to 20 cm depth) of Anchal soil and the lowest in the upper reaches (20 to 40 cm depth) of Kallayam soil (Table 5o).

Highly significant difference existed between the content of exchangeable iron in the three reaches. In the lower reaches the status of exchangeable iron was significantly higher than in the corresponding lower reaches.

There was also highly significant difference between the content of exchangeable iron in soils at two depths in the same location. At 0 to 20 cm depth it was generally higher compared to 20 to 40 cm depth.

Total manganese

From the results presented in Table 5p it may be

Table 5o. Chemical properties of soils - Exchangeable iron (me/100 g soil).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	0.056	0.050	0.025	0.022	0.014	0.011
2	Kallayam	0.049	0.045	0.021	0.020	0.010	0.005
3	Kulathupuzha	0.049	0.043	0.021	0.019	0.008	0.006
4	Neyyattinkara	0.049	0.043	0.022	0.019	0.008	0.006
5	Ottasekharamangalam	0.053	0.046	0.027	0.025	0.010	0.009
6	Palode	0.053	0.045	0.021	0.019	0.010	0.008
7	Punalur	0.050	0.038	0.020	0.019	0.009	0.006
8	Thalavur	0.053	0.050	0.027	0.025	0.018	0.016
9	Uzhamalakkal	0.054	0.038	0.018	0.017	0.008	0.010
10	Vellarada	0.051	0.046	0.019	0.021	0.016	0.016
11	Vembayam	0.029	0.031	0.009	0.009	0.008	0.010
12	Vithura	0.049	0.044	0.019	0.020	0.009	0.007
	Mean	0.049	0.043	0.020	0.019	0.010	0.009

CD between soils x depth = 0.004

" " reaches x depth = 0.002

" " soils x reaches = 0.004

Table 5p. Chemical properties of soils - Total manganese (ppm).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	390	353	372	336	332	290
2	Kallayam	420	490	429	416	332	386
3	Kulathupuzha	374	420	490	269	386	332
4	Neyyattinkara	478	507	382	350	360	416
5	Ottasekharamangalam	420	450	400	386	374	420
6	Palode	550	435	380	330	316	360
7	Punalur	380	360	300	326	330	298
8	Thalavur	410	470	410	420	330	366
9	Uzhamalakkal	390	420	486	288	372	354
10	Vellarada	427	510	398	366	397	422
11	Vembayam	410	460	397	375	362	412
12	Vithura	510	440	410	380	320	358
	Mean	430	443	400	354	351	368

CD between soils x depth = 72

" " reaches x depth = 36

" " soils x reaches

seen that total manganese content in the twelve locations varied from 269 ppm in the middle reaches of Kulathupuzha to 550 ppm in the lower reaches of Palode.

It was also found that the lower reaches were having more manganese than the middle and upper reaches.

There was also significant difference within the reaches with respect to their depths. The surface soils contained more manganese than the subsoil.

Available manganese

Available manganese in the different locations varied from 1.50 to 4.91 ppm (Table 5q). The highest value was recorded in the subsoil of the lower reaches of Kallayam and the lowest in the subsoil of the middle reaches of the Vellarada soil. Significant differences existed between the three reaches and also between depths. The lower reaches invariably contained more available manganese than the middle and upper reaches.

Total copper

The content of total copper in the different locations varied from 9 to 54 ppm. The maximum content was

Table 5q. Chemical properties of soils - Available manganese (ppm).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	3.50	2.54	2.03	2.34	1.63	2.09
2	Kallayam	3.23	4.91	2.63	2.86	2.21	2.85
3	Kulathupuzha	4.20	4.91	2.85	2.86	2.09	1.63
4	Neyyattinkara	3.10	2.86	2.21	1.63	2.10	2.80
5	Ottasekharamangalam	1.80	2.60	1.96	2.80	2.34	2.86
6	Palode	3.18	2.34	2.86	2.08	3.23	3.40
7	Punalur	3.42	3.10	2.10	2.34	1.81	2.05
8	Thalavur	3.10	3.85	2.90	2.70	2.26	2.80
9	Uzhamalakkal	4.80	4.90	2.85	2.09	1.68	3.20
10	Vellarada	2.85	2.80	1.85	1.50	3.10	3.45
11	Vembayam	1.80	2.10	1.86	2.10	2.28	2.95
12	Vithura	3.10	2.75	2.41	2.16	3.10	3.56
	Mean	3.17	3.31	2.37	2.28	2.31	2.80

CD between soils x depth = 0.66

" " reaches x depth = 0.33

" " soils x reaches = 0.81

observed in the surface soil of the upper reaches of Uzhamalakkal soil and the lowest in the sub surface sample of the upper reaches of Vithura (Table 5r).

A marked difference in the total copper content was observed due to depth of the soil. The content was generally higher in the surface than in the sub surface soils.

Available copper

It may be seen from Table 5s that the available copper in the twelve locations represented a very small fraction of the total copper and varied from 0.63 to 2.84 ppm. The highest value was recorded in the middle r eaches of Vithura soils and the lowest value in the middle reaches of Anchal.

There was no significant difference between the content of available copper in the soils at the three reaches. However, a marked difference was evident between the two depths, available copper being much higher in the surface than in the sub surface soils.

Table 5r. Chemical properties of soils - Total copper (ppm).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	45.0	32.0	36.0	30.0	54.0	50.0
2	Kallayam	35.0	32.6	36.5	30.1	15.0	12.5
3	Kulathupuzha	40.4	32.1	26.0	23.5	20.1	17.6
4	Neyyattinkara	28.5	26.1	30.2	18.4	16.0	12.0
5	Ottasekharamangalam	37.5	32.2	29.0	27.0	28.5	21.2
6	Palode	32.5	30.0	28.5	31.5	18.5	12.1
7	Punalur	45.5	32.5	27.0	27.0	20.0	15.5
8	Thalavur	48.0	24.0	15.0	27.0	18.0	15.0
9	Uzhamalakkal	48.6	29.5	18.5	15.0	54.0	39.0
10	Vellarada	28.0	27.0	19.5	18.6	15.0	17.2
11	Vembayam	40.5	32.0	35.2	31.0	19.5	15.0
12	Vithura	28.5	25.2	33.0	12.5	15.5	9.0
	Mean	38.2	29.5	27.8	24.3	24.5	19.0

CD between soils x depth = 8.4
" " reaches x depth = 4.2
" " soils x reaches =10.2

Table 5s. Chemical properties of soils - Available copper (ppm).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	0.88	1.10	1.05	0.63	1.80	1.20
2	Kallayam	1.10	1.87	0.80	0.90	1.10	0.95
3	Kulathupuzha	2.10	0.90	1.20	0.95	1.14	1.05
4	Neyyattinkara	0.84	1.42	1.00	0.81	1.42	0.95
5	Ottasekharamangalam	2.20	1.47	1.84	1.10	2.29	1.86
6	Palode	0.90	1.50	2.84	1.29	1.16	0.95
7	Punalur	2.15	2.0	1.86	1.15	1.29	0.95
8	Thalavur	0.88	1.10	2.10	1.50	1.10	0.95
9	Uzhamalakkal	1.15	0.82	1.20	0.95	1.80	1.25
10	Vellarada	1.50	0.95	2.40	1.85	1.21	0.85
11	Vembayam	2.10	1.85	1.80	1.15	1.81	0.90
12	Vithura	1.15	0.82	1.20	0.95	1.60	1.20
	Mean	1.41	1.31	1.55	1.09	1.47	1.08

CD between soils x depth = 0.46
" " reaches x depth = 0.23
" " soils x reaches = 0.56

Total zinc

Total zinc in the different soil samples was generally higher than the copper content and it varied from 72 to 490 ppm (Table 5t). It was significantly higher in the lower and middle reaches compared to the upper reaches.

There was also appreciable difference between the content of total zinc at two depths. Generally, it was higher in the surface than in the sub surface soils.

Available zinc

The available zinc in the different locations represented only a very small fraction of the total content. It varied from 0.14 to 4.10 ppm in the upper and lower reaches of Kulathupuzha and Uzhamalakkal soil respectively (Table 5u).

Highly significant difference existed among the three slopes in their status of available zinc and much difference between the two depths was noticed in all the locations.

Table 5t. Chemical properties of soils - Total zinc (ppm).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1.	Anchal	410	284	240	260	320	285
2	Kallayam	360	280	196	120	180	72
3	Kulathupuzha	288	264	118	140	144	124
4	Neyyattinkara	360	310	214	196	180	214
5	Ottasekharamangalam	420	144	240	96	124	180
6	Palode	376	290	262	190	120	180
7	Punalur	370	360	310	321	340	270
8	Thalavur	470	460	327	310	385	410
9	Uzhamalakkal	380	460	490	320	270	285
10	Vellarada	410	400	372	410	365	340
11	Vembayam	390	340	310	346	362	298
12	Vithura	374	416	480	473	380	368
	Mean	384	334	296	265	264	249

CD between soils x depth = 90

" " reaches x depth = 45

" " soils x reaches =110

Table 5u. Chemical properties of soils - Available zinc (ppm).

Sl. No.	Location	Lower reaches		Middle reaches		Upper reaches	
		0-20 cm	20-40 cm	0-20 cm	20-40 cm	0-20 cm	20-40 cm
1	Anchal	1.23	1.10	0.82	0.70	0.27	0.19
2	Kallayam	1.94	1.80	0.90	0.23	0.32	0.68
3	Kulathupuzha	1.30	1.20	0.56	0.48	0.36	0.14
4	Neyyattinkara	1.60	1.20	0.42	0.63	0.31	0.27
5	Ottasekharamangalam	0.83	0.32	0.24	0.76	0.45	0.32
6	Palode	1.86	1.42	0.86	0.78	0.76	0.32
7	Punalur	3.16	2.42	2.10	2.41	1.62	2.10
8	Thalavur	2.86	3.10	2.82	2.91	2.11	2.96
9	Uzhamalakkal	3.76	4.10	2.91	2.08	2.16	1.63
10	Vellarada	3.70	2.82	2.46	1.82	2.10	1.42
11	Vembayam	3.10	2.94	2.12	2.48	2.00	2.42
12	Vithura	3.20	2.56	2.86	2.56	3.10	2.82
	Mean	2.37	2.08	1.58	1.48	1.29	1.27

CD between soils x depth = 0.45

" " reaches x depth = 0.22

" " soils x reaches = 0.55

<u>Correlation between the physico-chemical properties of the soils and their physiographic position.</u>

It may be seen from Table 6 that maximum number of soil properties were related to each other in the soils of the lower reaches compared to the middle and upper reaches. In the lower reaches, degree slope was positively and significantly correlated to total nitrogen ($r = 0.58$), which in turn was related to organic matter and available P ($r = 0.69$ and 0.76). In the sub surface soils of the lower reaches also a similar relationship was noticed. A positive relationship between the status of available N, Ca & Mg was also evident in the surface and sub surface soils of the lower reaches.

In the surface and sub surface soils of the middle and upper reaches, nitrogen alone was significantly related to slope. Total nitrogen is correlated to available N, Mg and organic matter. It may also be noted from Table 6 that the physical properties of the soils of the three reaches did not show any definite relationship either between themselves or with the degree of slope of the land.

DISCUSSION

DISCUSSION

Notwithstanding the differences due to variations in the type of parent material and the macro and micro-climatic features of the different regions of Kerala, the undulating topography of the land appears to be the most important single factor responsible for the apparent differences in the physical and chemical properties of soils. This is more so in the case of the soils located on the slopes and foothills of the hills and hillocks scattered all over the mid land region of Kerala.

Differential response of the same species of crop at different positions on the slopes of hills and valleys even within a narrowly defined mapping unit, points to the existence of a gradient in fertility level brought about only by spatial variability due to the differences in the physiographic position of the land. Beckett and Webster (1971) and Warrick and Nielsen (1980) have expressed such variations in terms of spatial difference in particular attributes on properties of soils. The concept of soil forming factors (Jenny, 1941) does not, however, provide a sufficient explanation for spatial variability of soils brought about by factors other than climate, organism, topography and parent material interacting over various periods of time.

The soils selected for the present study have been formed from the same type of parent material and situated within an altitude of 20 to 150 metres such that the influence of groundwater was not marked in the upper and middle reaches. The lower reaches being cultivated to paddy, were subjected to management practices which destroy the soil structure and maintain a layer of 5 to 10 cm water during periods of paddy cultivation.

The soils possessed good internal drainage and the groundwater table did not interfere with the processes of eluviation and illuviation. The effect of vegetational cover also appeared to be less variable since they were of a more or less uniform stand in the various locations. The upper and middle reaches were cultivated to annuals and perennials whereas the lower reaches were mostly paddy fields.

The spatial variability in soil properties due to differences in physiographic position of the land alone is reflected in the diversity of physical and chemical characteristics of the soils selected for the present investigation.

Physical characteristics of soils

The presence of a higher proportion of the coarser particles and a lesser proportion of fine sand in the lower reaches compared to the upper and middle reaches indicates the preferential movement of the coarser particles down the slope compared to the finer ones. This observation can be attributed to the operation of gravitational forces accentuated by the larger size and mass acting on the coarser particles aiding in their downward movement during rainy seasons. The fine sand particles, though constituted only less than 30% of the coarser particles might have been probably held against the force of gravity in the upper and middle reaches due to their smallness in size and mass. The occurrence of a higher content of coarse and fine sand in the sub surface soils (20 to 40 cm) compared to that in the surface soils, points to a state of less mechanical eluviation and surface run off resulting in their greater deposition in the lower layers. Lal (1976) and Loganathan and Krishnamorthy (1976) have reported similar observations on the comparative downward mobility of coarse particles as well as silt and clay. A more or less uniform distribution of clay in the surface and sub surface layers points to a lesser rate of clay migration and mechanical eluviation compared to silt which showed a greater deposition in the surface rather than in the sub surface soils. Probably, these factors were less operative in the case of silt which comprises of larger sized particles than clay particles.

Soil aggregates

The larger soil aggregates of size more than 4 mm were maximum in the upper and middle compared to the lower reaches. At the same time, the smaller sized aggregates were distributed more or less uniformly in these different reaches. The lower proportion of larger aggregates in the lower reaches may be attributed to the washing down and breaking away of less stable, larger primary aggregates from the upper reaches. It may also be due to the lack of formation of stable and larger aggregates in the lower reaches due to the predominance of coarser sand particles rather than in the fine sand, which cannot presumably act as nuclei for aggregate formation. The disturbances or pedoturbations arising from land preparation and management for rice cultivation in the lower reaches may also account for the comparatively lower proportion of larger aggregates. A higher proportion of the stable aggregates in the sub surface soils points to their greater stability due to lesser disturbance and or due to the binding action of roots. The build up of a more compact plough pan in the sub surface layer can also contribute to the stability of aggregates. The slope of the land which ranges from 6 to 27 degrees may be more effective in bringing about greater leaching and eluviation than those located at a lower degree of slope. These observations are consistent with the well known effects of slope as a function in deciding the soil properties (Jenny, 1941).

Chemical properties

Chemical characteristics of soils not only are important from the nutrition of crops and fertility considerations, but also in following the pattern of release of nutrient elements from parent materials and their relative mobility under various situations.

Soil reaction

The soil reaction of the different locations, eventhough varied widely (pH 3.8 to 5.5) did not differ with respect to their depth in the profile or position on the land. This clearly suggests that the factors operative in the determination of soil reaction were uniform under both the situations.

Organic matter

The organic matter content was very high in some locations, and was generally associated with a high nitrogen content. This has helped to maintain a very narrow C/N ratio of 5:1 to a modest figure of 38:1. The role of organic matter in the enrichment and conservation of nutrients in the soil is most obvious. The existence of a positive correlation ($r = 0.57$) between organic matter and total nitrogen confirms the intimate relationship between nitrogen and organic matter in the soils studied. Similar relationship has been reported in literature (Russel, 1961; Fitz Patrick, 1980). However, the absence of such a relationship between organic matter and other nutrients, indicates that these nutrients are more associated with the inorganic rather than the organic components of the soil. Soil organic matter is considered to be of little significance as a direct source of plant nutrients other than nitrogen and phosphorus (Broadbent, 1953).

Mineral nutrients

Eventhough much difference could not be noticed in the status of availability of P and K, their total content was higher in the upper and middle compared to the lower reaches. The general trend in the distribution of P in the different reaches depicted a tendency for more or less uniform distribution in the surface and sub surface layers. The total and available P were maximum in the surface soils of the middle reaches.

Unlike total phosphorus, the available P status of the different soils exhibited marked differences with respect to their vertical distribution. The surface soils generally contained a higher level of available phosphorus. Since P is considered to be a comparatively immobile element (Clark, 1976) the greater enrichment of the surface soils may be attributed to the lack of downward mobility as in the case of other mobile elements. As water percolates through the soil profile, there tends to be a "chemical sieving" of dissolved inorganic P (Black, 1973). This arises as a result of the sorption of inorganic P by soil components. The accumulation and retention of inorganic P in the surface soil will depend on the nature and amount of P retaining components such as clay and sesquioxides present in the soil (Broadbent, 1953).

In the case of potassium the spatial differences due to variation in position and depth were not much marked, indicating their relatively less important role in affecting the status of total and available potassium at different physiographic positions.

The distribution of total calcium, however, revealed a greater tendency for its accumulation in the lower and middle reaches compared to the upper reaches. The contents of calcium and magnesium which were relatively much higher in the sub surface soils indicate a situation of greater mobility and migration of these elements both vertically and laterally. Relatively higher accumulation in the subsoil may also be due to the loss of Ca and Mg by surface run off from top soil.

Iron and manganese distribution also showed similar patterns, the lower reaches containing a higher content than the middle and upper reaches.

The available copper formed a greater proportion of the total content than the corresponding values for zinc. The distribution of these elements reflected only less significant vertical variation.

The results from the present study however, do not point to any regularity in the distribution of various characters used to measure the physical and chemical properties of soils. The presence of a higher amount of total as well as available Ca, Mg, Fe, Cu, Zn and Mn in the lower reaches is suggestive of the influence of slope of the land in affecting their movement along with surface run off. Probably, the more weathered and finer secondary minerals which carry these mineral elements and constitute a higher proportion of the smaller sized particles of the lower reaches, may account for this observation.

The correlation matrix has revealed a significant relationship between organic matter content and nitrogen as well as clay. Lack of correlation of organic matter with most other nutrients, is a clear evidence of the non-association of these nutrient elements with organic matter as would have normally expected. The relationship was significant only between total nitrogen, available phosphorus and clay with organic matter. At the same time, eventhough organic matter showed a marked difference in content with respect to the position of the soil on the slope as well as at the two depths, such variations were not evident in the case of available phosphorus and total nitrogen. Thus, it follows that eventhough the downward migration and mobility of organic matter is taking place to an appreciable extent, this is not significantly related to a corresponding shift in the status of available phosphorus and total nitrogen. While this was the situation in the top soil of the lower reaches, the lower layer of these soils showed only a much lesser degree of correlation. At the two depths of soils in the three reaches, degree slope was significantly correlated to total nitrogen alone, bringing out the influence of this factor in determing the nitrogen content of soils. Probably the washing down of the surface soil to the lower reaches, brings along the fraction of soil and organic matter where a major part of the soil nitrogen is residing.

The top part of the soil is constantly being disturbed and redistributed by running water. Generally, as water flows over the surface, varying amounts of soil are picked up in suspension and deposited lower down the slope, where they accumulate. The differentiation of soil materials due to lateral surface movement has been more pronounced in the distribution of nitrogen than any other nutrient.

Such soils on the slopes of hills are subject to a more frequent redistribution of soil nutrients, either losing through leaching or gaining through lateral in wash.

The vegetational cover of the soil at different reaches also may influence the retention and redistribution of nutrients as well as the different sized soil aggregates and soil particles. Barrows and Kilmer (1964) have shown that the vegetational cover may influence the loss of organic matter along with nitrogen and phosphorus.

Calcium and magnesium losses were found to be generally of minor significance.

The lower reaches cultivated to paddy provide a state of soil which is managed in such a way as to destroy the structure. A proportionally higher content of smaller sized aggregates in the lower reaches is a clear indication of the breaking down of larger aggregates to smaller ones during the operation of various management practices for rice.

Lack of appreciable differences between the physical and chemical properties of soils and their random distribution might be the resultant effect of the vegetational cover on the amount of precipitation reaching the soil surfaces (Fitz Patrick, 1980). The upper and middle reaches thickly cultivated to crops such as banana, tapioca, arecanut, coconut etc. bring an additional influence due to their canopy and stand. The part of the land which is not intercepted by the foliage directly receive an excess of precipitation which disrupts the surface matrix of soil. Water drops from leaves may cause a greater erosion since they may attain a greater terminal velocity. At the same time, heavy showers provide sufficient water which runs down through the stem or foliage causing greater leaching immediately around the tree. Therefore, the spatial variability in soils due to differences in slope and physiographic position can be different in bare and cultivated soils. While slope and altitude is more important in bare soils, the vegetational cover may provide a profound influence in cropped soils on sloping sites. Erosion is often the normal consequence, which can be aggravated or minimised depending upon the nature of the vegetational cover.

The higher plants also influence the soil in many ways. The root system acts as a binder to prevent soil erosion and through the operation of nutrient recycling, a delicate balance is set between the properties of soils at various depths. As Dahiya et al (1984) have pointed out, one might expect inorganic nutrient concentration to fluctuate more widely and rapidly than the nutrients contained in organic matter, which in turn might imply greater spatial variability of inorganic form of nutrients. On the other hand, the greater mobility of the inorganic than of organic form of nutrients may suggest that large spatial differences imposed by an input of these forms would be eliminated more quickly in the mobile form, thereby reducing spatial variability (Fitz Patrick, 1980).

The physico-chemical characters of the upper and middle reaches may thus be thought of as a product of the processes of erosion and nutrient recycling super imposed by the slope of the land. Such properties of the lower reaches may be viewed as a net result of the deposition and stratification processes operative through the agencies of surface run off and soil erosion in the upper and middle reaches.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

A study of the soils of South Kerala has been undertaken to investigate the variations in fertility status in relation to their physiographic position. Twelve locations were selected for this purpose and from each location soil samples occurring in the upper, middle and lower reaches were collected from depths of 0 to 20 cm and 20 to 40 cm. The sites were located at an elevation of 20 to 150 m with the degree of slope ranging from 6 to 27.

The lower reaches of all the locations were more or less level paddy fields. The middle reaches were cultivated to banana, pepper, coconut and tapioca and the upper reaches in addition to the above crops to perennials like coconut and rubber.

The soil samples were analysed to determine the distribution of various sized soil particles as well as water stable aggregates. Chemical properties such as pH, organic matter, total and available macro & micro nutrients etc. were also studied. The data have been subjected to statistical analysis so as to bring out differences in the physico-chemical properties of soils as a function of slope and depth brought about by their physiographical position.

The chief findings from the study are summarised below:

1. Generally, the proportion of coarse particles was greater in the lower reaches compared to fine particles. This is believed to be due to the preferential washing down slope of the heavier coarse particles aided by the operation of gravitational forces acting across the slope.

2. The lower reaches which consisted of waterlogged paddy fields showed a higher content of smaller sized soil aggregates compared to the upper and middle reaches where water stable aggregates of more than 4 mm were prominent. Destruction of larger aggregates due to management operations for rice may probably account for this condition. It may also be due to the lack of formation of larger aggregates in the lower reaches due to the predominance of coarser sand rather than fine sand which probably cannot act as building units for larger aggregates.

3. Water stable aggregates were higher in the sub surface than in the surface soils. This may be due to lesser mechanical disturbances as well as to the binding action of roots and organic matter.

4. The organic matter content was very high in some locations and was generally associated with a high nitrogen content also, giving rise to a C:N ratio ranging from 5:1 to 38:1. A positive correlation between total nitrogen and organic matter has also been noticed.

5. There was no such relationship between organic matter and other plant nutrients. This indicates that these nutrients might be more associated with the inorganic components rather than the organic matter in the soil.

6. Eventhough the total content of P & K was higher in the upper and middle compared to the lower reaches, the distribution of available P & K did not follow any such pattern.

7. Available P was generally higher in the surface soils. The greater enrichment of P in the surface soil is considered to be due to the lack of downward mobility

of P and to a greater retention and fixation by clays and sesquioxides.

8. The distribution of a relatively higher content of Ca & Mg in the sub surface soils is considered to be the consequence of a loss of these nutrients by run off from surface soil resulting in a relatively higher enrichment in the subsoil.

9. The contents of Fe & Mn were greater in the lower reaches compared to the upper and middle reaches.

10. Available Cu formed a greater proportion of its total content than the corresponding values for zinc and much variation was not noticed in the lateral and vertical distribution of Cu and Zn in the soil.

The results from the present study however do not suggest any regularity in the distribution of various characters used as indices of the physical and chemical properties of soil. The greater accumulation of nutrient elements other than N, P & K in the lower reaches highlights the influence of the slope in aiding the downslope movement of more weathered surface soil which contains a greater proportion of the finer secondary fractions which carry these mineral elements.

The vegetational cover of the soil at different reaches seem to super impose the influence of slope in the retention and redistribution of nutrients as well as different sized soil aggregates and soil particles by altering the amount and velocity of water running through. The root system of the plants also acts as a binder to prevent soil erosion and through the operation of nutrient recycling, a delicate balance is set between the properties of the soils at various depths and slopes.

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*Originals not seen

APPENDICES

Table 6. Correlation Matrix - Lower reaches 0-20 cm depth.

Slope degree	Total N	Available N	Available P	Available K	Available Ca	Available Mg	Organic matter	Clay
	0.5816*	0.2993	0.5167	0.0093	0.3970	0.4490	0.6219*	0.1130
		0.3843	0.7636**	0.1321	0.2054	0.2301	0.6997*	0.1666
			0.2206	0.5074	0.6025	0.6955*	0.3100	0.1441
				0.2820	0.2095	0.0543	0.4051	0.0114
					0.1648	0.6673*	0.1705	0.0022
						0.4601	0.2494	0.2330
							0.2397	0.2572
								0.5803*

20-40 cm depth

Slope degree	Total N	Available N	Available P	Available K	Available Ca	Available Mg	Organic matter	Clay
	0.7151**	0.2941	0.3244	0.0693	0.1956	0.1912	0.4676	0.5560*
		0.0436	0.3596	0.2479	0.1948	0.0780	0.8366**	0.2279
			0.2003	0.2289	0.2638	0.1144	0.1114	0.0812
				0.0238	0.0903	0.4560	0.2858	0.2837
					0.2640	0.3308	0.3402	0.3672
						0.5046	0.3160	0.8102**
							0.1081	0.5257
								0.1016

Table 6 (Contd.)

Middle reaches 0-20 cm depth.

0.6239*	0.2337	0.4628	0.1458	0.1178	0.4493	0.0615	0.2296
	0.2390	0.0408	0.4745	0.1498	0.1157	0.4957	0.4101
		0.5095	0.3449	0.1039	0.4468	0.0068	0.4688
			0.4974	0.1642	0.3481	0.0479	0.3071
				0.0847	0.0699	0.3994	0.2730
					0.4559	0.4357	0.1224
						0.4227	0.0392
							0.2569

20-40 cm depth

0.0083	0.7884**	0.3984	0.0096	0.0154	0.4163	0.0199	0.3219
	0.1638	0.1390	0.4578	0.0453	0.0406	0.1450	0.5090
		0.2413	0.0913	0.1118	0.4580	0.2033	0.3532
			0.3920	0.5098	0.0526	0.1287	0.1056
				0.5334	0.3093	0.1860	0.3900
					0.4453	0.2298	0.1326
						0.3313	0.4466
							0.3357

Table 6 (contd.)

Upper reaches 0-20 cm depth.

0.5807**	0.0494	0.1708	0.2821	0.3793	0.2376	0.2615	0.1952
	0.6116*	0.0684	0.3235	0.2123	0.6375*	0.6723*	0.0231
		0.0756	0.3680	0.4295	0.4670	0.4635	0.2572
			0.5472	0.1369	0.3308	0.1482	0.1374
				0.0616	0.3356	0.3249	0.0634
					0.1803	0.3606	0.4478
						0.4243	0.0260
							0.0320

20-40 cm depth

0.7345*	0.0588	0.1176	0.4068	0.0875	0.0469	0.2623	0.0302
	0.2177	0.0782	0.4419	0.0275	0.3491	0.5604	0.1690
		0.1665	0.2407	0.0960	0.5261	0.0917	0.1415
			0.1751	0.5039	0.3787	0.1840	0.2940
				0.1470	0.1587	0.0139	0.0532
					0.6065*	0.5121	0.6479*
						0.4142	0.7693**
							0.5390

FERTILITY INVESTIGATIONS ON THE SOILS OF SOUTH KERALA IN RELATION TO THEIR PHYSIOGRAPHIC POSITIONS

BY

G. WILFRED GODWIN

THESIS

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ABSTRACT

ABSTRACT

A study of the soils of South Kerala has been undertaken to investigate the variation in fertility status in relation to their physiographic position. Twelve locations from the districts of Trivandrum and Quilon were selected and from each location soil samples from upper, middle and lower reaches were collected from depths of 0 to 20 cm and 20 to 40 cm. The elevation of the location varied from 20 to 150 metres and the degree of slope from 6 to 27.

The lower reaches of all the locations were more or less level paddy fields. The middle reaches were cultivated to banana, pepper, coconut and tapioca and the upper reaches in addition to the above crops perennials like coconut and rubber.

The soil samples were analysed to determine the distribution of various sized soil particles as well as water stable aggregates. Chemical properties such as pH, organic matter, total and available macro and micro nutrients etc. were also studied. The data have been subjected to statistical analysis so as to bring out differences in the physico-chemical properties of soils

as a function of slope and depth brought about by their physiographical position.

Generally, the proportion of coarse particles was greater in the lower reaches compared to fine particles. This is believed to be due to the preferential washing down slope of the heavier coarse particles aided by the operation of gravitational forces acting across the slope. The lower reaches which consisted of water logged paddy fields showed a higher content of smaller sized soil aggregates compared to upper and middle reaches were water stable aggregates of more than 4 mm were prominent. Distruction of larger aggregates due to management operations for rice may probably account for this condition. It may also be due to the lack of formation of larger aggregates in the lower reaches due to predominance of coarser sand rather than fine sand which probably cannot act as building units for larger aggregates. Water stable aggregates were higher in the sub surface than in the surface soils. This may be due to lesser mechanical disturbances as well as to the binding action of roots and organic matter.

The organic matter content was very high in some locations and was generally associated with a high nitrogen content also, giving rise to a C:N ratio ranging 5:1 to 38:1. A positive correlation between total nitrogen and organic matter has also been noticed. There was no such relationship between organic matter and other plant nutrients. This indicates that these nutrients might be more associated with the inorganic components rather than the organic matter in the soil.

Eventhough the total content of P and K was higher in the upper and middle compared to the lower reaches, the distribution of available P and K did not follow any pattern. Available P was generally higher in the surface soils. The greater enrichment of P in the surface soil is considered to be due to the lack of downward mobility of P and to a greater retention and fixation by clay and sesquioxides. The distribution of a relatively higher content of Ca and Mg in the sub surface soils is considered to be the consequence of a loss of these nutrients by run off from surface soil and resulting in a relatively higher enrichment in the subsoil.

The content of Fe and Mn was greater in the lower reaches compared to the upper and middle reaches. Available Cu formed a greater proportion of its total content than the corresponding values for zinc and much variation was not noticed in the lateral and vertical distribution of Cu and Zn in the soil.

The results from the present study however do not suggest any regularity in the distribution of various characters used as indices of the physical and chemical properties of soil. The greater accumulation of nutrient elements other than N, P and K in the lower reaches highlights the influence of the slope in aiding the downslope movement of more weathered surface soil which contains a greater proportion of the finer secondary fractions which carry these mineral elements.

The vegetational cover of the soil at different reaches seem to super impose the influence of slope in the retention and redistribution of nutrients as well as different sized soil aggregates and soil particles by altering the amount and velocity of water running through. The root system of the plants also acts as a binder to prevent soil erosion and through the operation of nutrient recycling, a delicate balance is set between the properties of the soils at various depths and slopes.