STUDIES ON THE MOISTURE RETENTION CHARACTERISTICS OF ALLUVIAL SOILS OF KERALA

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Studies on the moisture retention characteristics of alluvial soils of Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,
7-9-1983.

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Dated:

CERTIFICATE

Certified that this thesis entitled "Studies on the moisture retention characteristics of alluvial soils of Kerala" is a record of research work done independently by Smt. Prameela, K.P., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

R. Vikraman Nair,
Chairman,
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CERTIFICATE

We, the undersigned, members of the Advisory Committee of Smt. Prameela, K.P., a candidate for the degree of Master of Science in Agriculture with major in Agronomy, agree that the thesis entitled "Studies on the moisture retention characteristics of alluvial soils of Kerala" may be submitted by Smt. Prameela, K.P., in partial fulfilment of the requirement for the degree.

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Introduction

INTRODUCTION

Scheduling irrigation based on percentage depletion of available water is currently being followed for upland crops. It is based on the principle that the rate of uptake of water by plants decreases with increasing percentage of depletion and that beyond a threshold value, crop yield gets adversely affected. While arriving at the frequency of irrigation, an attempt is made to replenish soil water content to field capacity when all the readily available water is just exhausted. A pre-requisite for arriving at the readily available water content of any soil, is an estimate of the field capacity and wilting coefficient values. To estimate these values using laboratory methods is often not handy. It is, however, well established that the water content of soil at any given suction is strongly related to the quantity and quality of colloidal fractions. If a mathematical expression giving the relation of water content at a given matric potential with the contents of organic carbon and textural fractions can be arrived at, it would then be convenient to estimate storage capacities of readily available water. This expression should be valid as long as the quantity of colloidal components can be assumed to be uniform.

It is well-established that there exists almost a constant relation between soil moisture tension and water content. Working out such a relationship will be useful in arriving at the ease and rate of uptake of water by plants at any given total water content.

To estimate the water retention properties of soils of Kerala, laboratory studies were initiated since 1981, starting with the laterite soils. The present study on riverine alluvium is the second of the series. The main objectives of the study are

1. To study the moisture retention characteristics of alluvial soils of Kerala at varying levels of matric potential.

2. To arrive at the degree of relationship of the moisture retention with content of organic carbon and textural separates and to work out prediction models.

3. To work out available water content of alluvial soils to aid in irrigation scheduling.

Review of Literature

REVIEW OF LITERATURE

A brief review of the work done on soil moisture retention, availability and their relation to soil texture and organic carbon is summarised below.

Concept of soil water availability to plants

The concept of soil water availability, though never defined clearly in physical terms, has caused controversy of opinion among different scientists. Veihmeyer and Hendrickson (1927, 1949, 1950, 1955) claimed that soil moisture is equally available throughout a particular range of soil moisture, from an upper limit to a lower limit, both of which are characteristic and constant for any given soil. They established that plant functions remained unaffected by any decrease in soil moisture until the onset of lower limit of available moisture, at which plant activity stopped abruptly. This theory was in existence for many years, particularly in the field of irrigation management.

However, this view was contradicted by the more detailed studies of soil moisture phenomena on physical grounds. The experimental evidences of Staple and

Lehane (1941), Alyers and Campbell (1951), Army and Kozluski (1951), Richards and Wadleigh (1952), Kelley (1954) and Bernstein and Pearson (1954) showed that soil moisture availability to plants actually decreased with decreasing soil wetness, and that a plant might suffer water stress and reduction of growth considerably before the wilting point was reached.

Khudairi et al. (1962) opined that the concept of equally available soil moisture cannot be applied to herbaceous plants. With green gram and cotton, soil moisture between the upper limit and 75 per cent of available water gave the best plant growth. Moisture levels of 50 per cent of upper limit between irrigations according to them are the lowest in which plants can be grown economically.

Other workers tried to compromise between these opposite views, by dividing the so called "available range" of soil moisture into "readily available" and decreasingly available ranges, and searched for a "critical point" somewhere between the upper and lower limits as an additional criterion of soil water availability.

The upper limit of available moisture had been fixed as field capacity (Israelsen and West, 1922; Veihmeyer and Hendrickson, 1927) which was defined by Vetterlein (1960) as the range of moisture in which water movement by slow seepage is taking place. Wilcox (1962) defined the upper limit of available moisture as the highest moisture content that included all moisture available for consumptive use, but excluded all drainage below the root area. But he argued that the upper limit did not accord with field capacity.

Kramer (1969), taking field capacity as the upper limit of available moisture found that it was not a true equilibrium value, but in that condition, the water movement was so slow that the water content did not change appreciably between measurements.

It has long been recognised that soil wetness is not a satisfactory criterion for availability. Hence attempts were made to correlate the water status of plants with the energy state of soil moisture. The soil moisture constants were therefore defined in terms of potential values, which could be applied universally, rather than in terms of soil moisture (Richards and Weaver, 1944; Slater and Williams, 1965).

In the laboratory, field capacity is measured by simulating the tension which develops during drainage in the field by the use of pressure membranes/ plates or tension tables.

Regarding the tension to be applied, there had been differing views. Richards and Weaver (1944) and Colman (1947) proposed a tension of 0.3 bar or 330 cm of water on soil samples which had been dried, ground and sieved, while Marshall (1959) recommended a tension of 100 cm on undisturbed samples. Maclean and Yager (1972) investigating on some Zambian soils found that moisture determinations at 1/3 atmosphere led to under estimates of field capacity in almost all samples he used. One-third atmosphere most closely approximated field capacity in fine textured soils but for most samples, 1/10 or 1/20 atmosphere measurements gave closest estimates of field capacity.

Rivers and Shipp (1978) determined water retention percentages of sandy soils at field capacity under field conditions and also at 1/10, 1/15, and 1/20 bar suctions. They obtained no single soil water suction, producing water retention values adequately representing field capacity for all textures.

Lal (1979), while preparing moisture retention characteristics of some Nigerian soils, observed that for most of the soils, the field capacity was estimated at 60 or 100 cm water suction rather than at 0.3 bar.

Whereas field capacity has been used to refer to the upper limit of available soil water, permanent wilting point has been used to refer to the lower limit. The permanent wilting percentage is based upon the wilting coefficient concept of Briggs and Shantz (1912) and has been defined as the root-zone soil wetness at which the wilted plant can no longer recover turgidity even when it is placed in a saturated atmosphere for 12 hours.

Work by a number of scientists like Briggs and Shantz (1911, 1912), Richards and Wadleigh (1952) have shown that the soil water at wilting approximates -10 to -20 bars, with a mean value of about -15 bars.

An equation was developed by Lehane and Staple (1960), relating permanent wilting percentage (PWP) to the 15 atmosphere percentage (FAP) as, PWP = 0.35 + 0.833 FAP.

The work of Gromann and Medina (1962) indicated that greater part of the soil moisture available to plants was held under a tension of 8 atmosphere.

In a field study, permanent wilting percentage in a loam soil varied between a moisture tension of 10 atmosphere with sunflower and 20 atmosphere with maize. In a clay loam soil, permanent wilting was near 15 atmospheres with sunflower (Sykes and Loomis, 1963). Maclean (1970), and later Maclean and Yager (1972) found the 15 atmosphere measurement as a satisfactory estimate of wilting point.

Slatyer (1957) strongly criticized the concept of PWP as a soil constant. According to him wilting actually occurred due to the loss of turgor in the leaves, which in turn occurred when there is a dynamic balance between the water potential in the soil and the water potential in the plant. However, because of the particular shape of soil moisture characteristic curve significant changes in water potential usually follow small changes in water content, so that for many practical purposes, the permanent wilting percentage can be regarded as an important soil value (Kramer, 1969).

Theoretical understanding of the state and movement of water in the soil, plant and atmosphere has shown the static concepts as "the soil water constants" to be physically meaningless. But, from the agronomic point of view, they should be useful to convey some ideas which have come to carry a particular meaning by long usage.

Moisture retention in relation to texture

The amount of moisture retained by a soil at any given suction is dependent on the composition and arrangement of soil particles. Thulasidharan (1983) has made a review of the work done during the period from 1939 to 1981, on the relationship between moisture retention and particle size distribution. The conclusions drawn by him from the review are as follows:

(i) Soil moisture content at all tensions showed strong relation with the fine fractions, silt and clay.

(ii) The relation between available moisture content and content of fine fractions had been variable, there being an increase in the content of available water with increasing clay content in some cases and a decrease in some others especially at higher clay contents.

(iii) There had been consistent positive correlation between the content of silt and available water content.

As the work on this aspect has been reviewed by Thulasidharan (1983) recently, such of those items of work included in his review are not included in this text. The additional references that could be collected were included and a brief account of such items of work is given below.

Work of Shaykewicz and Zwarich (1968), Lal (1979), Chen and Wang (1979) and Benkenstein and Kruger (1977) have revealed the occurrence of highly significant correlation between textural separates and soil moisture constants. Within a textural class, the retention is decreased by increased content of coarse fragments (Peterson et al., 1968; Kohad et al., 1975). Soong and Yap (1977) and Talha et al. (1979) reported that soils with more sand retained significantly less water than soils dominating in clay, at field capacity as well as at permanent wilting point. Experimental results of Satyanarayana et al. (1977) and Thulasidharan (1983) also supported this view, but they also included silt as a component positively correlated with moisture retention.

Thulasidharan, working with laterite soils, observed the preponderance of gravel, which decreased the retention capacity of the soil considerably. Rivers and Shipp (1978) reported that the percentage of very fine sand alone and in combination with the percentages of silt and clay were significantly correlated with soil water values.

Lund (1959), while studying the alluvial soils in Lousiana, obtained a positive correlation of 0.626 between silt content and range of available moisture. His data indicated that clay held moisture at suction values too high for plant availability. An inverse relationship was found to exist between sand and available moisture range. Kowalinski and Giedroj (1968) calculated the available moisture capacity of sand, loam, clay and loess as 9, 22, 17 and 28 per cent respectively.

Salter and Williams (1969) developed equations incorporating texture and organic carbon to arrive at the moisture retention at the limiting tensions. They obtained an accuracy of 9 to 22 per cent of the measured value for the upper limit, ± 8 to 16 per cent for the lower limit and ± 26.7 to 32.5 per cent for the available moisture. Maclean (1970) and Maclean and Yager (1972) conducted multiple linear regression analysis producing an equation relating available water to percentages of textural separates, organic carbon and sample depth. Multiple regression equations developed by Hollis *et al.* (1977) included only organic carbon, clay and/or silt content. 74 to 77 per cent of the variation in retained water capacity and 49 to 57 per cent of the variation in available water were explained by these equations. Thulasicharan (1983) also developed prediction equations to determine the moisture retention at 0.3 and 15 bar pressures of 2 mm sieved soil fraction of laterite soils of Kerala incorporating the particle size distribution and content of organic carbon as follows:

a) Moisture percentage at 0.3 bar (Y_1)

$$= -80.9088 + 0.7647\ x_1 + 1.1465\ x_2 + 1.2407\ x_3 + 0.8974\ x_4 + 0.9429\ x_5.$$

b) Moisture percentage at 15 bar (Y_2)

$$= -12.9880 - 0.3575\ x_1 + 0.4033\ x_2 + 0.5214\ x_3 + 0.1344\ x_4 + 0.2714\ x_5$$

where x_1 = organic carbon per cent;

x_2 = clay per cent;

x_3 = silt per cent;

x_4 = fine sand per cent;

x_5 = coarse sand per cent.

Moisture retention in relation to organic carbon content

Thulasidharan (1983) has reviewed the literature on the relation between organic carbon content and soil moisture retention for the period from 1959 to 1981. His main conclusions are summarised below.

(i) Moisture retention and content of available water were positively correlated with the organic carbon content in most cases.

(ii) There were reports of a lack of such relation presumably because the favourable effect of organic matter was masked by the dominant effect of the content of the fine fractions and also because the inherent difference in organic carbon content was associated with textural changes.

Other works have also shown the positive influence of organic carbon in increasing the retained moisture (Grossman and Medina, 1962; Puri and Mahajan, 1962; Juncker and Manson, 1967; Velayutham and Raj, 1971; Maclean and Yager, 1972; Burns and Rawitz, 1981).

Krol (1963) has explained the influence of organic matter on available water as being due to the reduction in the amount of air pores and increase in the amount of pores filled with water.

Petersen *et al.* (1968) reported that effect of organic carbon was associated with 15 atmosphere moisture, but not with 1/3 atmosphere moisture in the soils studied. In sandy soils, treatment with compost showed an increased field capacity, but had less marked influence on available moisture, owing to associated increase in the wilting percentage (Tremechi, 1968).

Soong and Yap (1977) obtained non-significant relation between organic carbon content and moisture release characteristics. Thulasidharan (1983) also reported such a non-significant relationship in laterite soils. He assumed this to be due to the low organic matter content and the over riding effects of fine fractions.

Materials and Methods

MATERIALS AND METHODS

The investigation involving soil samples collected from five districts of Kerala was conducted in the College of Horticulture, Vellanikkara, during the period from September, 1982 to July 1983.

1. Selection of site

Five soil series of riverine alluvium, established by the soil survey unit of the Department of Agriculture were selected in five districts of Kerala. The selected soil series included Karamana series located at Karamana in Trivandrum district, Kallada series located at Kunnathur in Quilon district, Punnamattom series at Keezhumadu in Ernakulam district, Chaliyar series at Mavoor in Calicut district and Puthur series at Puthur in Trichur district. Morphological descriptions of the typifying pedon of each series are given in Appendix I.

2. Sampling procedure

In each of the five series, pits of 1.5 m depth were taken at three locations. Five soil samples were taken from each pit at depth intervals of 30 cm, by scraping the sides of the pit.

3. Determination of bulk density

Core samplers of 10 cm length and 4.4 cm diameter were used for drawing samples for the bulk density determination. After removing the upper 10 cm layer of soil from each depth, the core sampler was driven vertically through the side of the pit. The collected samples were then transferred to polythene bags and packed without loss of soil.

In the laboratory, the bulk density was determined after drying in an electric oven at 105-110°C for 24 hours.

4. Measurement of moisture retention

The bulk samples were first air dried, crushed, and sieved through 2 mm sieve. Pressure plate apparatus (Richards, 1947) was used to determine the soil moisture retention. The retention was measured at applied pressures of 0.3 bar, 1 bar, 3 bars, 5 bars, 10 bars and 15 bars. Soil samples were put in rubber rings and saturated overnight. These were then transferred to pressure plates, already saturated overnight, and the required pressure was applied. It was then allowed to equilibrate for 48 hours after which the samples were collected, and moisture content determined gravimetrically, after drying in an electric oven at 105-110°C for 24 hours. Each sample was run thrice for moisture retention study.

One bar pressure plate was used for determining the moisture content at 0.3 bar and 1 bar pressures, 5 bar plate for 3 bar and 5 bar pressures, and 15 bar plate for 10 bar and 15 bar pressures.

5. Determination of available moisture

The moisture held in between 0.3 bar and 15 bar pressures was taken as the available moisture, on weight basis. The volumetric moisture retention was obtained by multiplying these retention values with the bulk density of each sample. The available moisture on volume basis was finally calculated as the difference between the volume of moisture held at 0.3 bar and 15 bar pressures.

6. Particle size distribution analysis

The mechanical composition of the 2 mm sieved fraction of the soil was found out by International pipette method (Piper, 1966) using sodium hydroxide as the dispersing agent.

7. Determination of organic carbon

Organic carbon content of the 0.2 mm sieved fraction of soil was determined by Walkley and Black rapid titration method, as proposed by Jackson (1958).

Statistical analysis

The moisture retention capacity of the soil was correlated to the organic carbon content and texture, using multiple regression analysis as described by Snedecor and Cochran (1967). Regression models were developed to predict the field capacity, wilting coefficient and available moisture in riverine alluvium from a knowledge of textural composition and organic carbon content. Moisture characteristic curve was also arrived at for the riverine alluvium.

Results

RESULTS

In this chapter, the results of the investigation are presented.

1. Moisture retention by profiles

Data on the moisture retention at six applied pressures varying from 0.3 to 15 bars are presented in Table 1. The data indicate a trend of decreasing moisture content with increasing pressure. The rate of decrease, however, varied markedly with series, profile and even with different layers within a profile.

Though the values of the series were widely different, the overall mean values were worked out to represent the alluvial soils.

When the applied pressure was raised from 0.3 to 1 bar, 47.90 per cent of the overall mean available moisture was extracted, and 23.52 per cent was depleted by increasing the suction from 1 to 3 bars. When the pressure was raised from 3-5, 5-10 and 10-15 bars, it removed 6.72 per cent, 12.61 per cent, and 9.24 per cent respectively, of the total available water. Most of the available water (71.42 per cent) was thus removed when the pressure reached 3 bars. An attempt was made to work out a suitable prediction model for moisture characterisation and the best fit obtained was the Cobb Douglas function.

The five series under study varied considerably in their moisture holding capacities. The mean moisture percentage at field capacity on weight basis gave a range of 21.4 (Karamana series) to 32.2 (Chaliyar series), while permanent wilting percentage varied from 12.1 (Kallada series) to 16.9 (Chaliyar series). The highest mean content of available water was in the Punnamattom series (15.8 per cent), the Karamana series giving the lowest value of 8.7 per cent. The overall mean moisture percentage at field capacity was 25.8 and at permanent wilting point, it was 13.9, thus giving a value of 11.9 per cent for available water.

A comparison of the various profiles representing a series showed that substantial variation also existed within a given series. For example, in the Punnamattom series one profile had an available moisture percentage of 18.2, while another one had only 12.8. This sort of

Table 1. Moisture retention by the soil (percentage by weight)

a) Karamana series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	18.8	15.2	13.3	12.8	12.0	11.1	7.7
30 - 60	21.4	16.8	15.1	14.5	13.6	12.6	8.8
60 - 90	20.6	16.5	14.8	14.4	13.4	12.6	8.0
90 -120	23.3	18.8	16.5	15.9	14.8	13.8	9.5
120 -150	22.8	18.6	16.3	15.5	14.6	13.5	9.3
Mean	21.4	17.1	15.2	14.6	13.7	12.7	8.7

b) Kallada series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	20.5	14.8	12.5	11.7	10.7	10.0	10.5
30 - 60	27.2	20.6	18.2	17.3	16.3	15.2	12.0
60 - 90	24.5	18.8	16.5	16.1	14.9	13.9	10.6
90 -120	18.4	13.9	12.0	11.5	10.7	9.8	8.6
120 -150	21.4	16.1	14.2	13.5	12.6	11.6	9.8
Mean	22.4	16.8	14.7	14.02	13.0	12.1	10.3

c) Punnamattom series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	21.8	16.1	13.1	12.3	10.8	9.9	11.9
30 - 60	30.0	21.7	17.0	16.2	14.3	13.0	17.0
60 - 90	32.0	23.7	19.5	18.5	16.5	15.1	16.9
90 -120	32.2	24.3	20.7	20.2	18.5	16.7	15.5
120-150	36.5	27.4	23.0	22.4	20.0	18.7	17.8
Mean	30.5	22.6	18.7	17.9	16.0	14.7	15.8

d) Chaliyar series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	27.3	20.6	17.2	15.3	12.9	11.5	15.8
30 - 60	30.7	24.2	21.8	20.5	18.0	17.1	13.6
60 - 90	31.6	25.2	22.8	21.4	19.1	17.5	14.1
90 -120	35.4	26.9	24.5	22.8	20.3	19.0	16.4
120 -150	36.0	27.6	25.1	23.5	21.0	19.5	16.5
Mean	32.2	24.9	22.3	20.7	18.3	16.9	15.3

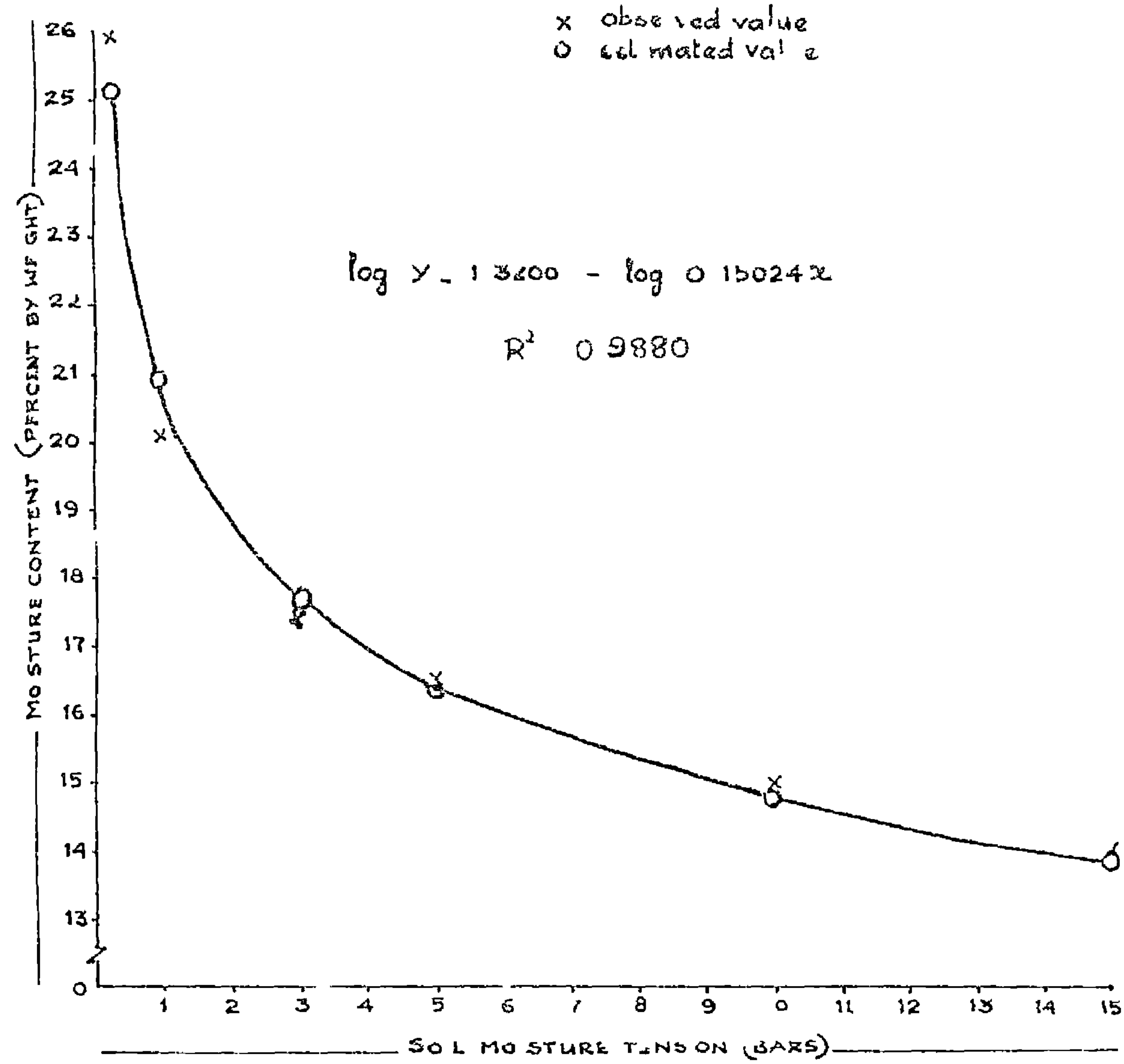
e) Puthur series

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	17.2	13.4	11.1	10.5	9.1	8.5	8.7
30 - 60	21.8	18.3	15.5	15.0	13.5	12.8	9.0
60 - 90	23.5	19.9	16.9	16.4	15.1	14.2	9.3
90 -120	24.0	20.0	17.0	16.8	15.2	14.5	9.5
120 -150	26.6	22.5	19.4	18.6	17.0	16.3	10.3
Mean	22.6	18.8	16.0	15.5	14.0	13.3	9.3

f) Overall mean moisture retention at different tensions (percentage by weight)

Depth cm	Soil moisture tension (bars)						Available water
	0.3	1.0	3.0	5.0	10.0	15.0	
0 - 30	21.1	16.0	13.4	12.5	11.1	10.2	10.9
30 - 60	26.2	20.3	17.5	16.7	15.1	14.1	12.1
60 - 90	26.4	20.8	18.1	17.4	15.8	14.7	11.7
90 -120	26.7	20.8	18.1	17.4	15.9	14.8	11.9
120 -150	28.7	22.4	19.6	18.7	17.0	15.9	12.8
Mean	25.8	20.1	17.3	16.5	15.0	13.9	11.9

F g 1 - MO STURE CHARACTERISTIC CURVE FOR THE ALLUVIAL SOILS OF KERALA



variation was apparent in other series also. Data on the retention values of different profiles of each series are not presented and discussed.

In all the series except the Kallada and Chaliyar series, the least content of available moisture was in the topmost layer, and there was an increase in moisture content with depth. However, this observed change with depth was not consistent for all the profiles.

2. Soil properties
2.1 Organic carbon

Data on the organic carbon percentages of the different series and their mean values are presented in Table 2.

The overall mean organic carbon content was 0.378, while the range of mean values for the different series was from 0.311 (Kallada series) to 0.455 (Chaliyar series). The topmost layer of 0-30 cm had the highest organic carbon content in all the series with a decreasing trend in the content with depth. The overall mean organic carbon percentage for the surface layer was 0.625 which dropped to 0.238 per cent in the fourth layer (90-120 cm).

Table 2. Organic carbon contents of the different series (percentage)

Depth cm	Karamana series	Kallada series	Punnamattom series	Chaliyar series	Puthur series	Overall mean
0 - 30	0.526	0.404	0.840	0.690	0.663	0.625
30 - 60	0.336	0.305	0.502	0.536	0.503	0.436
60 - 90	0.297	0.315	0.274	0.415	0.392	0.339
90 -120	0.169	0.207	0.183	0.358	0.271	0.238
120 -150	0.298	0.325	0.137	0.274	0.231	0.253
Mean	0.325	0.311	0.387	0.455	0.412	0.378

2.2 Texture

The particle size distribution and textural class of soils of the different series are presented in Table 3.

The mean clay percentage of the different series ranged from 21.6 (Puthur series) to 31.3 (Chaliyar series) with an overall mean value of 25.2. Similarly the mean silt percentage was 24.6, while the mean values for series varied between 17.9 and (Kallada series) and 30.2 (Punnamattom series). With an overall mean of 30.4, the mean fine sand percentage ranged from 23.6 (Karamana series) to 34.8 (Kallada series). Data on coarse sand fraction also showed variation between series, the mean values being in the range from 6.6 for Chaliyar series to 31.7 in the case of Karamana series. The overall mean content was 17.6 per cent.

Taking the fine fractions (Clay + silt) as a whole, the Chaliyar series was found to contain the highest amount (60.8 per cent), the Kallada series having the least (40.2 per cent). The overall mean worked out to 49.8 per cent.

The variation in texture with depth was not conspicuous and consistent.

Table 3. Textural composition of the soil (percentage)

a) Karamana series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	25.3	13.0	27.1	32.9	Sandy clay loam
30 - 60	25.6	20.6	21.9	30.6	Sandy clay loam
60 - 90	23.0	19.5	24.4	32.3	Sandy clay loam
90 -120	29.6	16.9	23.5	29.6	Sandy clay loam
120 -150	20.6	22.8	21.3	33.3	Sandy clay loam
Mean	24.8	18.6	23.6	31.7	Sandy clay loam

b) Kallada series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	24.8	14.5	40.8	16.7	Sandy clay loam
30 - 60	25.0	25.3	38.1	9.2	Sandy clay loam
60 - 90	22.4	22.4	39.3	14.4	Sandy clay loam
90 -120	20.5	12.0	28.8	37.3	Sandy clay loam
120 -150	18.9	15.4	27.2	36.0	Sandy loam
Mean	22.3	17.9	34.8	22.7	Sandy clay loam

c) Punnamattom series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	18.8	19.7	26.2	33.0	Sandy loam
30 - 60	24.6	23.6	39.3	8.5	Sandy clay loam
60 - 90	29.5	33.9	28.3	5.3	Clay loam
90 -120	27.0	36.5	28.7	5.2	Loam
120 -150	29.4	37.4	29.7	2.3	Clay loam
Mean	25.9	30.2	30.4	10.9	Loam

d) Chaliyar series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	24.1	23.2	36.6	11.8	Sandy clay loam
30 - 60	29.8	31.7	30.1	6.1	Clay loam
60 - 90	30.6	31.6	30.4	5.7	Clay loam
90 -120	35.4	34.4	23.5	3.2	Clay loam
120 -150	36.5	26.7	27.9	6.0	Clay loam
Mean	31.3	29.6	29.7	6.6	Clay loam

e) Puthur series

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	13.8	20.7	41.2	23.3	Sandy loam
30 - 60	29.9	20.2	28.8	17.8	Sandy clay loam
60 - 90	28.1	24.7	33.6	12.4	Sandy clay loam
90 -120	22.1	26.6	35.4	13.9	Sandy clay loam
120 -150	14.2	41.4	29.1	13.7	Loam
Mean	21.6	26.7	33.6	16.2	Sandy clay loam

f) Overall mean textural composition

Depth cm	Clay	Silt	Fine sand	Coarse sand	Textural class
0 - 30	21.4	18.2	34.4	23.5	Sandy clay loam
30 - 60	27.0	24.3	31.6	14.4	Sandy clay loam
60 - 90	26.7	26.4	31.2	14.0	Sandy clay loam
90 -120	26.9	25.3	28.0	17.8	Sandy clay loam
120 -150	23.9	28.7	27.0	18.3	Sandy clay loam
Mean	25.2	24.6	30.4	17.6	Sandy clay loam

Based on the mean textural composition of the entire profile, the soils were classed as loam in Punnamattom series, as clay loam in Chaliyar series and as sandy clay loam in all the other series.

2.3. Bulk density

Data on the bulk density values for the different series together with their overall mean for the whole samples are furnished in Table 4.

The variation in the bulk densities of the different series was not conspicuous. They were in the range of 1.36 g cc^{-1} in the case of Punnamattom series to 1.47 g cc^{-1} for Putnur series, with an overall mean value of 1.410 g cc^{-1}. The change in bulk density with depth was inconsistent for different profiles.

Moisture retention and available water on volume basis were determined by multiplying the corresponding values on weight basis with the bulk density of each. Data on these are presented in Table 5.

Volumetrically, the overall mean content of available water was 16.7 p r cent, with 36.4 and 19.7 per cent as the moisture retention at 0.3 and 15 bars,

Table 4. Bulk densities of the different series (g cc^{-1})

Depth cm	Karamana series	Kallada series	Punnamattom series	Chaliyar series	Puthur series	Overall mean
0 - 30	1.332	1.351	1.325	1.435	1.312	1.351
30 - 60	1.392	1.374	1.335	1.370	1.614	1.417
60 - 90	1.380	1.393	1.343	1.514	1.426	1.411
90 -120	1.384	1.479	1.330	1.364	1.560	1.423
120 -150	1.392	1.469	1.450	1.513	1.418	1.448
Mean	1.376	1.413	1.357	1.439	1.466	1.410

Table 5. Moisture retention on volume basis for different series (percentage by volume) at 0.3 and 15 bars

Depth cm	Karamana series			Kallada series			Punnamattom series		
	0.3	15	Available water	0.3	15	Available water	0.3	15	Available water
0 - 30	25.0	14.8	10.2	27.7	13.5	14.2	28.9	13.1	15.8
30 - 60	29.8	17.5	12.3	37.4	20.9	16.5	40.1	17.4	22.7
60 - 90	28.4	17.4	11.0	34.1	19.4	14.7	43.0	20.3	22.7
90 -120	32.2	19.1	13.1	27.2	14.5	12.7	42.8	22.2	20.6
120 -150	31.7	18.8	12.9	31.4	17.0	14.4	52.9	27.1	25.8
Mean	29.4	17.5	11.9	31.6	17.1	14.5	41.5	20.0	21.5

Table 5 (Contd.)

Depth cm	Chaliyar series			Puthur series			Overall mean		
	0.3	15	Available water	0.3	15	Available water	0.3	15	Available water
0 - 30	39.2	16.5	22.7	22.6	11.2	11.4	28.7	13.8	14.9
30 - 60	42.1	23.4	18.7	35.2	20.7	14.5	36.9	20.0	16.9
60 - 90	47.8	26.5	21.3	33.5	20.2	13.3	37.4	20.8	16.6
90 -120	48.3	25.9	22.4	37.4	22.6	14.8	37.6	20.9	16.7
120 -150	54.5	29.5	25.0	37.7	23.1	14.6	41.6	23.1	18.5
Mean	46.4	24.4	22.0	33.3	19.6	13.7	36.4	19.7	16.7

respectively. The available moisture percentage on volume basis ranged from 11.9 to 22.0 between series. At 0.3 bar the variation in moisture retention was from 29.4 to 46.4 per cent, while the same at 15 bar suction was 17.1 to 24.4 per cent. The available water content was lowest in the top 0 to 30 cm layer. The change in available water content with depth was not consistent.

3. Correlation studies

The correlation coefficients for the moisture percentages at different suctions with organic carbon and texture are furnished in Table 6. These were arrived at from the individual values of all profiles and depths of the different series.

The content of clay gave significant positive correlation with the moisture contents at different tensions. The silt fraction also followed a similar trend. The coarse fractions gave negative correlations with moisture retention values. With coarse and fine sand fractions, the coefficients were always high and highly significant, excepting in the case of fine sand at 0.3 bar when it was significant only at 5 per cent.

Table 6. Correlation coefficients of moisture retention and available water with organic carbon content and textural composition

	Organic carbon	Clay	Silt	Fine sand	Coarse sand
0.3	0.108	0.680**	0.809**	-0.240*	-0.777**
1.0	0.117	0.696**	0.842**	-0.317**	-0.745**
3.0	0.099	0.724**	0.823**	-0.370**	-0.706**
5.0	0.081	0.722**	0.828**	-0.384**	-0.695**
10.0	0.051	0.729**	0.749**	-0.404**	-0.675**
15.0	0.047	0.720**	0.822**	-0.405**	-0.671**
Available water	0.158	0.509**	0.645**	-0.005	-0.757**

* Significant at 5 per cent level

** Significant at 1 per cent level

Table 7. Inter correlations of av-ilable moisture with organic carbon and textural separates

	Available moisture	Organic carbon	Clay	Silt	Fine sand	Coarse sand
Available moisture	1.000	0.158	0.509**	0.645**	-0.005	-0.757**
Organic carbon		1.000	0.128	0.095	-0.151	-0.038
Clay			1.000	0.336**	-0.385**	-0.511**
Silt				1.000	-0.332**	-0.641**
Fine sand					1.000	-0.316**
Coarse sand						1.000

** Significant at 1 per cent level

The correlation between the moisture retention values and the organic carbon percentage were not significant at any of the six applied tensions.

Available water content also followed a similar pattern with clay and silt contents giving significant positive correlation and the coarse sand fraction giving a negative, significant correlation. The effects of fine sand and organic carbon content on available water were not significant.

Intercorrelations among textural separates, organic carbon and available moisture were worked out and are presented in Table 7.

Prediction equations incorporating organic carbon content and texture were developed to estimate the moisture retention at 0.3 and 15 bars and also the available moisture percentage. These equations are presented below. The analysis of variance is given in Appendices 2, 3 and 4.

a) Moisture percentage at 0.3 bar (Y_1)

$$Y_1 = 10.3387 + 0.3405\, x_1 + 0.3610\, x_2 + 0.0030\, x_3 - 0.1170\, x_4 + 0.0176\, x_5 \quad (R^2 = 0.87)$$

$$Y_2 = -14.1100 + 0.4309\ x_1 + 0.4198\ x_2 + 0.1575\ x_3 + 0.1547\ x_4 - 1.6651\ x_5 \quad (R^2 = 0.91)$$

c) Percentage of available water (Y_3)

$$Y_3 = 24.7534 - 0.0936\ x_1 - 0.0618\ x_2 - 0.1576\ x_3 - 0.2748\ x_4 + 1.6790\ x_5 \quad (R^2 = 0.65)$$

where x_1 = clay per cent;

x_2 = silt per cent;

x_3 = fine sand per cent;

x_4 = coarse sand per cent;

x_5 = organic carbon per cent.

Discussion

DISCUSSION

The results obtained in the investigation are discussed in this chapter.

1. Soil properties

The organic carbon content showed little consistent variation between series. However, with depth, there was a steady decrease in its content, the topmost layer of 0-30 cm giving the highest value in all the series.

The series, however, varied in their textural composition and were classified into different textural classes. There was change from layer to layer also within some of the series. Almost the same degree of textural variation was noted between profiles of the same series (Data not presented). Such variations were to be normally expected for alluvial soils of recent origin. Averaging out such widely different values within a series though may not give an idea of the textural status of a series, it was done to give an indication of the overall textural status. Such a comparison shows the soils of Karamana series to be sandy clay loam, those of Kallada series to be sandy loam and sandy clay loam Punnamattom series in the range from sandy loam to clay loam, Chaliyar series in sandy clay loam and clay loam and Puthur series to be in the range from sandy loam to loam at different depths. There was no trend of textural change with depth in any series. The overall average of the percentages of textural separates in all the series indicates the mean texture to be sandy clay loam in the entire depth upto 150 cm.

2. Moisture retention by profiles

Data on the moisture retention values at different pressures from 0.3 to 15 bars are presented in Table 1. Moisture content varied inversely with suction, the rate of change differing with series, profiles and with layers. This difference in the content has apparently resulted from textural variation. The range of field capacity between the different depths of the different series was from 17.2 to 36.5 per cent and that of wilting coefficient from 8.5 to 19.5. The overall mean field capacity value was 25.8 and wilting coefficient 13.9.

A prediction model was developed for moisture characterisation and Cobb Douglas function was found to be the best fit. The graphical presentation is given in Fig.1. As is indicated by the graph, fifty per cent of the available water was removed just above a suction of one bar, and at three bars, above 70 per cent of the available water was depleted. Thus there is need for irrigation as the soil moisture attains a tension of one bar in the case of crops with maximum percentage of permissible depletion of 50 which may be extended upto three bars in those with depletion values around 70-75 per cent.

As could be expected from the wide differences in texture between profiles, moisture retention values showed concomitant variations between series, profiles within a series, and depths within a profile. Comparing between the mean values of the different series, Chaliyar series recorded the highest field capacity of 32.2, Kallada series gave the lowest value of wilting point (12.1 per cent). The available water content was the highest in Punnamatton series. It is to be noted, however, that these numerical differences appear to be incidental location effects and not any consistent series wise trends.

One trend that was more or less consistent was that the lowest retention values at all tensions were noted in the surface layers of all the series. A comparison with textural composition would indicate the higher percentage of sand as the factor responsible for this.

3. Correlation studies

Table 6 furnishes the correlation coefficients between moisture percentage at different suctions and organic carbon and texture. As expected, clay and silt fractions gave significant positive correlation with moisture retention at all suctions and with available moisture. Both coarse and fine sand fractions gave negative significant correlation. An increasing influence of fine sand fraction in deciding the moisture retention at increasing tensions is noted as evidenced by a steady increase in coefficient values with increasing pressures.

The relationship of organic carbon content with moisture retention and available water was positive, but not significant even at 5 per cent level. In Punjab soils where the organic matter content ranged between

0.1 and 0.4 per cent, Sekhon and Arora (1967) obtained similar results. Since colloidal fraction is the main determining factor of moisture retention, a significant correlation was expected with organic carbon. The observed non-significance may be due to the dominance of fine textural components and low content of organic matter. This view was supported by Jamison and Kroth (1958) and Thulasidharan (1983).

With the objective of predicting the available water content and the moisture contents at 0.3 and 15 bars from the content of organic matter and textural composition, multiple regression equations were worked out. These are given below.

a) Moisture percentage at 0.3 bar (Y_1)

$$Y_1 = 10.3387 + 0.3405\ x_1 + 0.3610\ x_2 + 0.0030\ x_3 - 0.1170\ x_4 + 0.0176\ x_5\ (R^2 = 0.87).$$

b) Moisture percentage at 15 bars (Y_2)

$$Y_2 = -14.1100 + 0.4309\ x_1 + 0.4198\ x_2 + 0.1575\ x_3 + 0.1547\ x_4 - 1.6651\ x_5\ (R^2 = 0.91)$$

c) Percentage of available water (Y_3)

$$Y_3 = 24.7534 - 0.0936\ x_1 - 0.0618\ x_2 - 0.1596\ x_3 - 0.2748\ x_4 + 1.6790\ x_5\ (R^2 = 0.65)$$

where x_1 = clay per cent;

x_2 = silt per cent;

x_3 = fine sand per cent;

x_4 = coarse sand per cent;

x_5 = organic carbon per cent.

The predictability values of these equations were 87 per cent, 91 per cent, and 65 per cent for the retention values at 0.3 bar, and 15 bars and for the available water capacity respectively. Those values are high especially for field capacity and wilting coefficient values indicating thus, that these equations can be dependably used for calculating these moisture constants from texture and organic matter content. It is also to be concluded that the variables considered can define moisture retention with reasonable accuracy showing again that the differences in the quality of soil organic matter and fine fractions in the alluvial soils are not substantial.

A comparison with the wide variations noted between profiles, horizons and series would further indicate the necessity for calculating moisture retention and available water capacity for each location rather than relying on the mean values obtained.

4. Available water capacity on volume basis

One of the objectives of the investigation was to work out the available water content as a tool for scheduling irrigation in alluvial soils. From what has been discussed, it is to be concluded that there must be more of reliance on available water capacity calculated for each location rather than on mean values. However, as bulk density variation between samples is not high, the overall mean value of 1.41 g cc^{-1} may be used to multiply with gravimetric water content.

Summary

SUMMARY

A study was conducted in the College of Horticulture, Vellanikkara during the period from September 1982 to July 1983 to investigate the moisture retention characteristics of alluvial soils of Kerala. Soil samples representing five series were collected from fifteen profiles at five depths from the districts of Trivandrum, Quilon, Ernakulam, Trichur and Calicut. Moisture retentions at six tensions viz., 0.3, 1, 3, 5, 10 and 15 bars were estimated and the moisture contents were correlated with organic carbon content and mechanical composition of the soil by simple and multiple regression analysis. The results of the study are summarised below.

1. Moisture retention characteristic indicates that 50 per cent of the available moisture is extracted at a tension just above 1 bar. More than 70 per cent depletion occurred at the tension of 3 bars. There was change in retention with series, profiles, and depths and there was no consistent trend of variation. The mean moisture contents at 0.3 and 15 bars were 25.8 per cent and 13.9 per cent, respectively.

2. The organic carbon content of the surface layer had a mean value of 0.625 per cent, while the mean values for the entire depth of 150 cm varied from 0.311 per cent to 0.455 per cent between series. The role of organic carbon was not found important in determining the moisture retention indicated by its nonsignificant correlation with moisture retention at all the tensions.

3. The clay and silt contents gave significant positive correlation with the moisture content at all the tensions ranging from 0.3 bar to 15 bars.

4. There was a significant negative correlation between the contents of coarse fractions (fine and coarse sand) and moisture retention at all the suctions.

5. Multiple regression equations with high predictability were developed to arrive at the available moisture content and moisture retention at 0.3 and 15 bars from a knowledge of the contents of organic carbon and textural constituents. The high predictability indicates that the difference in the quality of organic matter and fine fractions are not substantial.

6. A procedure for arriving at the available water content from the determinations of bulk density, content of organic carbon, and textural components is suggested.

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* Originals not seen

Appendices

Appendix I. Morphological descriptions of typifying pedon of each series

a) Karamana series

Horizon	Depth (cm)	Description
Ap	0-18	Dark yellowish brown (10 YR 4/4) Sandy loam; structureless, single grain; loose; roots plenty; permeability rapid; clear wavy boundary.
C_1	18-40	Strong brown (7.5 YR 4/6) sandy loam; structureless, loose; roots plenty; permeability rapid; gradual, wavy boundary.
C_2	40-66	Brown (7.5 YR 4/4) Sandy loam; structureless, loose; roots few; permeability rapid; diffuse wavy boundary.
C_3	66-140+	Strong brown (7.5 YR 5/5) sandy loam; massive; roots few; permeability rapid.

Source: Soils of Kerala by Soil Survey Branch, Department of Agriculture, 1978.

b) Kallada series

Layer	Depth (cm)	Description
1	0-14	Dark brown (7.5 YR 4/4) clay loam; weak granular; firm, slightly sticky and slightly plastic; abundant roots; moderately slow permeability; clear smooth boundary.
2	14-75	Dark, reddish, brown (5 YR 3/4) clay loam; weak medium, sub angular blocky; firm, sticky and plastic; roots plenty; slow permeability; clear smooth boundary.
3	75-130+	Reddish brown (5 YR 4/4) clay; moderate, medium sub angular blocky; firm, sticky and plastic. Few roots, slow permeability.

Source: Soil survey Report of the Command Area of Kallada Irrigation Project, State - Kerala by Soil survey Staff, Department of Agriculture (S.C. Unit), Kerala, Report No.31, 1975.

c) Punnamattom series

Layer	Depth (cm)	Description
1	0-43	Pale brown (10 YR 6/3) silty loam; medium weak crumb structure; moist friable, slightly sticky and plastic; plentiful roots; gradual wavy boundary; moderately rapid permeability; clear smooth boundary.
2	43-113	Yellow (10 YR 7/6) silty clay loam; medium moderate sub angular blocky structure; firm, slightly sticky and slightly plastic; few roots; presence of mica flakes; gradual smooth boundary; moderate permeability.
3	113-140+	Strong brown (7 YR 5/6) silty clay; coarse sub angular blocky structure; firm, sticky and plastic, roots absent; moderately slow permeability.

Source: Office of the Asst. Director of Soil Survey, Perumbavoor.

d) Chaliyar series

Horizon	Depth (cm)	Description
Ap	0-32	Dark brown (7.5 YR 4/4) silt loam; weak medium, granular; friable, slightly sticky and non-plastic; abundant fine roots; clear smooth boundary; moderate permeability; pH 5.8.
B2 1	32-110	Reddish brown (5 YR 4/4) loam; massive, breaking into weak medium subangular blocky; friable, slightly sticky; gradual smooth boundary; plentiful roots; moderate permeability; pH 6.2.
B2 2	110-160+	Reddish brown (5 YR 4/3) loam; massive, breaking into weak medium subangular blocky; friable, slightly sticky; moderate permeability; pH 6.0

Source: Soils of Kerala, by Soil Survey Branch, Department of Agriculture, 1978.

e) Puthur series

Horizon	Depth (cm)	Description
1	0-27	Dark reddish brown (5 YR 3/4), sandy loam; moderate, fine, subangular blocky; friable moist; nonsticky, non plastic; abundant, common roots, moderate permeability; gradual, smooth boundary.
II	27-95	Dark reddish brown (5 YR 3/4) sandy clay loam; moderate fine subangular blocky; friable; non-plastic, slightly sticky; fine medium roots; moderate permeability; abrupt smooth boudary.
III	95-130	Dark reddish brown (5 YR 3/4); clay loam; moderate, fine subangular blocky; friable, slightly sticky, slightly plastic; few medium sized roots; moderate slow permeability.

Source: Office of the Assistant Director of Soil Survey, Trichur.

Appendix 2. Analysis of variance for the multiple regression equation of moisture content at 0.3 bar, organic carbon content and particle size distribution

Source	Sum of squares	df	Mean squares	F
Total	4867.5	74		
Regression	4251.00	5	850.2	95.21**
Deviation from regression	616.5	69	8.93	

** Significant at 1 per cent level

Appendix 3. Analysis of variance for the multiple regression equation of moisture content at 15 bars, organic carbon content, and particle size distribution

Source	Sum of squares	df	Mean squares	F
Total	1677.75	74		
Regression	1523.40	5	304.680	136.2**
Deviation from regression	154.35	69	2.237	

** Significant at 1 per cent level

Appendix 4. Analysis of variance for the multiple regression equation of available moisture, organic carbon content, and particle size distribution

Source	Sum of squares	df	Mean squares	F
Total	1248.00	74		
Regression	810.68	5	162.136	25.58**
Deviation from regression	437.32	69	6.338	

** Significant at 1 per cent level

STUDIES ON THE MOISTURE RETENTION CHARACTERISTICS OF ALLUVIAL SOILS OF KERALA

By

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ABSTRACT OF A THESI

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ABSTRACT

An experiment was conducted in the College of Horticulture, Vellanikkara during the period from September 1982 to July 1983 to study the moisture retention characteristics of alluvial soils of Kerala. Soil samples representing five series located at different districts were collected from fifteen profiles at five depths. Moisture contents were determined at six applied pressures, viz., 0.3, 1, 3, 5, 10 and 15 bars. The moisture retention was correlated with the organic carbon content and texture of the soil by simple and multiple regression analysis.

The study revealed that 50 per cent of the available moisture was depleted at a tension just above one bar, and at 3 bar more than 70 per cent of the available water was extracted. The ranges in the field capacity and permanent wilting point were found to be 21.4 to 32.2 and 12.1 to 16.9 respectively, and the overall mean values 25.8 and 13.9.

The correlation study showed that the fine fractions (clay and silt) have significant positive

correlation with moisture retention. Both coarse and fine sand fractions gave significant negative correlation. The relationship of organic carbon content with moisture retention and available water was positive, but not significant even at five per cent level.

Prediction equations were developed to determine the available moisture content from known values of textural components and organic carbon content. The coefficients of determination obtained were high indicating that the difference in the quality of soil organic matter and fine fractions in the alluvial soils are not substantial.