EFFECT OF ELEVATION AND RAINFALL ON THE PHYSICO-CHEMICAL PROPERTIES OF THE SOILS OF THE HIGHRANGES OF KERALA

BY

K. CHANDRASEKHARAN NAIR, B. Sc., B. Sc. (Ag.)

THESIS

Submitted in partial fulfilment of the requirements
for the Degree of Master of Science in Agriculture (Agricultural Chemistry)
of the University of Kerala

DIVISION OF AGRICULTURAL CHEMISTRY
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE
VELLAYANI TRIVANDRUM

1969

C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Sri K. Chandrasekharan Nair under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

(P. KUMARA PILLAI)
PRINCIPAL

(M.M. KOSHY)
Addl. Professor of Agrl. Chemistry
and Agricultural Chemist.

AGRICULTURAL COLLEGE & RESEARCH INSTITUTE,
VELLAYANI : TRIVANDRUM.

AUGUST, 1969.

ACKNOWLEDGEMENTS

The author desires to place on record his deep felt appreciation and thanks to :

Dr. M.M. Koshy, Additional Professor of Chemistry and Agricultural Chemist for suggesting the problem and for the unstinted help and inspiring criticism at every stage of this investigation and in the preparation of this thesis;

Dr N.S. Money, Professor of Chemistry for his valuable advice in the planning and execution of this work;

Prof. P. Kumara Pillai, Principal, for providing necessary facilities for undertaking this study;

Dr. R.S. Iyer, Sri P.R. Ramasubramanian and Smt. T. Pankajakshy Amma, Junior Professors of Agricultural Chemistry for the keen interest shown in persuing the thesis and for offering constructive criticism;

Sri K.N.K. Nair, Chief Scientific Officer, Kannan Devan Hills Produce Co. Ltd., for the immense help and guidance given in collecting the soil samples from High Ranges;

The members of the Staff and his collegues of the Division of the Agricultural Chemistry for much help rendered;

The Government of Kerala for deputing him for Post-graduate course which enabled him to undertake this investigation.

K. CHANDRASEKHARAN NAIR.

C O N T E N T S

-:::O:::-

INTRODUCTION

INTRODUCTION

The characteristics of a soil are determined for the most part by climatic influences such as precipitation, temperature, evaporation, humidity and wind velocity, by the nature of the vegetative cover, by the composition of the parent material from which the soil is derived and by the topography of the land.

The importance of climate and elevation on the development of soil characteristics cannot be over emphasised. Jenny (1941) by attributing functional concepts to soil forming processes evolved the following equation depicting the role of climate on the development of soil properties.

$$S = f\,(mT)\ o, r, p, t$$

	S	=	f (mT) o,r,p,t
Where	S	=	Soil property
	m	=	Moisture
	T	=	Temperature
	O	=	Organism
	r	=	relief
	p	=	parent material
	t	=	time

The climatic factors express themselves through the moisture and energy they contribute to an environment. The rainfall, which is a component of climate, imprints its effect on the soil through the cycle of water which enters the soil and which is used for the production of organic matter or for hydration and hydrolysis or is released by the reverse process and removed through evaporation, transpiration and percolation.

Several works to study the influence of climate and elevation on the development of soil properties have been undertaken by Hirth (1926), Costin (1955), Dames (1955) and Muir (1955). Among the investigations on Indian soils, the work of Sen and Deb (1941, 1949), Ray Chaudhuri (1943, 1957, 1965) Dhir (1967) and Gopalaswmay (1967) deserve special mention. Vijayachandran (1963) and Dhanaraj (1966) have studied the effect of rainfall and elevation on the properties of soils in Kerala and Mysore States.

The present investigation to study the influence of rainfall and elevation on soil properties is confined to the High Ranges of Kerala where the elevation ranges from 600 metres to 2100 meteres and rainfall varies from 325 Cm. to 625 Cm. The main objectives of the investigations are:-

(1) to study the physical and chemical properties of the soils as influenced by rainfall and elevation;

(2) to assess the extent of soil deterioration due to high rainfall and elevation.

The investigation is of special practical significance in the management of the soils of the High Ranges. The High Ranges has a highly significant place in the economy of Kerala as the dollar earning crops especially tea are grown in this area. The Kannan Devan Hills produce Co. Ltd., alone cultivate about 45,000 acres of land under tea. Every year the plantation spends about Rs.70-80 lakhs on manuring alone and even if 40-50% of the soluble nutrients are leached below the root zone of the crop, the loss is tremendous and of serious consequence. It is hoped that this study will throw some light on the leaching loss of nutrients in the soils of the High Ranges and that the inferences drawn will be applicable to the high-level plantations of Kerala.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

It was Dokuchaev (1899) who first considered soil as the result of the combined activity and reciprocal influence of parent material, plant and animal organisms, climate, age of land and topography. Joffe (1936) classified the factors involved in the process of soil formation into two, viz; active and passive. The passive factors included parent material, topography, and time and the active factors were comprised of the elements of biosphere, atmosphere and hydrosphere.

Vanzijl (1934) reported that in north-east Transwaal, laterite soils were formed on any kind of geological formation.

In the laterite soils of Mauritius Craig and Halais (1934) observed that under increased rainfall red soils were formed by means of lateritic decomposition without a high leaching factor, whereas brownish yellow highly laterite soils were derived from lateritic weathering followed by a high leaching factor.

Vander Merwe (1935) studied the soils of Transwaal and found that two different soil types had developed under conditions of heavy rainfall and high humidity.

From a soil survey of Puerto-Rico Roberts (1942) observed that there was no specific relationship betwe n rainfall zones and soil groups.

In the soils of Bundelkhand Mukerjee and Agarwal (1943) observed that hot summers followed by heavy rainfall favoured weathering and consequent leaching coupled with the topography of the region gave rise to different types of soils.

Viswanath and Ukyl (1944) observed that geological differences might be obliterated under the influence of climate and that soils with similar prop rties might be covering the most varied rock systems. They divided India longitudinally into four broad divisions based on Meyer's N.S. quotient.

Costin (1955) observed that in Australia under conditions of increased precipitation the climatic sequence of soils on basalt were chernozems, chocolate soils and transitional chernozems.

Dames (1955) describing the soils of Java noted the occurrence of red laterite soils, brown laterite soils and humus brown soils derived from similar basic volcanic rocks under different rainfall conditions.

On the soils of Scotland Muir (1956) noticed very pronounced effect of rainfall. Hill peats, peaty podzols and peaty gleis occupied the high rainfall regions whereas brown forest soils and non-calcareous gleis were formed in areas where the rainfall was lower.

Donahue (1958) stated that any soil profile is the result of both the direct, as well as the indirect action of centuries of climatic forces.

Mohr (1913) found that in Java, the average temperature was largely a function of elevation above sea-level. He divides the island into four climatic zones based on elevation. Describing the soils of these zones he concluded that laterite was formed in tropical low-lands with abundant rainfall and podsolization occurred in the tropical high mountain zones with high rainfall and middle laterite temperature. In the hill zones with lower temperature than the low lands transitional stages between these two were found.

In the Kumaoan hills Mukerjee and Das (1940) found that three different soil types had developed, namely podzols, brown forest soils and red loams. They have given descriptions of the soil formations under the temporate climate observed in that hilly area.

Jenny (1941) stated that soil properties varied in the same direction with increasing altitude.

Retzer (1948) investigated the characteristics of soils developed from basalt under successive climatic vegetational zones of Western Colorado with elevation varying from 5000 to 10800 feet. He found many of the soil properties altering regularly with variation in altitude.

Costin and Hallsworth (1952) observed that soil properties do not vary in the same direction with increasing altitude. They noticed that in the Monaro region of New South Wales, at lower extremes, soil formation was limited by insufficient moisture and in upper extremes by insufficient temperature.

Lames (1955), studying the soils of Java, noticed the formation of red laterites at elevations below 300 metres brown laterites between 300-1000 metres and humus brown soils at altitudes above 1000 metres.

EFFECT OF RAIN FALL ON SOIL PROPERTIES

I <u>Rainfall and physical properties</u>

a) <u>Colour</u>

Ritcher (1931), describing the soils of Hawaii, stated that the soils showed all gradations of colour from almost pure yellow through the different shades of brown and red to grey and black in the different rainfall regions.

Durairaj (1951), in his study of the soil types of south India in relation to their colour and physical properties, observed that the orange hue of colour was closely associated with the composition of clay minerals.

(b) Physical properties

The physical properties of a soil are dependent principally upon its colloidal content.

Keen and Rackzkowski (1921) investigated the relationship between porespace and clay content and found that these two were positively correlated. The correlation between specific gravity and clay content was found to be negative. Volume of expansion was found to be directly connected to the percentage of clay.

Marchand (1924) determined the specific gravity, porespace, water holding capacity and volume expansion of soils by the Keen Rackzskowski method and observed that certain of the above properties could be roughly correlated with the clay content of the soil.

Coutts (1929) studied the volume expansion of Natal soils in relation to their clay content and obtained a positive correlation between the two.

Jenny and Leonard (1934) observed positive correlation between annual rainfall and clay content of soils of temperate regions.

Wilcox (1939) reported that the sand content of soils was negatively correlated with the maximum water holding capacity.

Joachims and Kandiah (1947) in their study of the soils of Ceylon found that a high correlation existed between clay content and the water-holding capacity.

Costin and Hallsworth (1952) observed that in the Alpine humus soils of South Wales, silt and clay were a maximum at an elevation of 5600-6000 feet and that these decreased significantly with increase, as well as decrease of altitude. This was attributed to the optimum temperature and moisture conditions prevailing in the sub-Alpine regions at altitudes of 5000-6000 feet.

Sinha et al (1957), in their study of the morphology of some red soils of Ranchi in relation to topography, concluded that down the slope the depth of profiles increased, the texture varied from sandy to clayey and the structure changed from single grain to granular or blocky.

Harradine and Jenny (1958) observed that soil texture became finer with increase in rainfall as a result of more intense weathering but the relationship was not linear. High rainfall is less effective on texture than low rainfall, possibly on account of higher run off at high precipitations.

Unnikrishnan (1961) stated that above 60" of rain the physical properties of laterite soils were not influenced by variations in rainfall.

In a study of Nilgiri soils Mahalingam (1962) found that clay content has no relationship to rainfall. He found a significant correlation between clay content and water-holding capacity and a positive correlation between loss on ignition and clay content.

Dhanaraj (1966) found that moisture and water holding capacity did not show any significant correlation with rainfall or elevation but a close correlation existed between water holding capacity and pore space.

II <u>Rainfall and Chemical properties</u>

Crowther (1930) found that the silica-sesqui oxide ratios of the clay fraction were correlated negatively with rainfall.

Craig and Halais (1934) found that the silica-alumina ratio was lower and the iron oxide-alumina ratio constant in the high rainfall laterite areas of Mauritius.

In a comparative study of several Indian soils, Ukyl et al (1944) found that there was considerable decrease in the silica - alumina ratios with increase in the annual precepitation.

Ray Chaudhuri and Mian (1944) observed a comparitively low silica-alumina ratio and silica-sesquioxide ratio for the west coast soils formed under conditions of high rainfall.

Tsuneo Tamura (1956) found that the clay content of paxton soil clays increased abruptly at rainfalls ranging from 20-25".

In the red soils of Mysore State Puttaswamy Gowda (1960) observed that under high Rainfall conditions leaching of calcium from soils lowered the pH and the silicate structures tended to disintegrate. Consequently the silica so released tended to accumulate in the lower horizons.

Unnikrishnan (1961) concluded that alumina and total sesquioxides increased and the silica sesquioxide ratio decreased progressively with increasing rainfall.

Dhanaraj (1966) found in high level laterites a high percentage of the sesqui-oxide.

III Rainfall and soil reaction

In a study of Maquilling soils Aristorenas (1937) found no relation between the pH and depth of soil.

In the case of the red soils of Mysore State, Puttaswamy Gowda (1960) indicated that under high rainfall conditions leaching of calcium from soils lowered the pH. Under conditions of low rainfall the case was reverse.

In his study of the soils of Madras State Nambiar (1963) had indicated that increase in rainfall resulted in a progressive increase in the hydrogen ion concentration and prevalence of soil acidity. He obtained a significant negative correlation between pH and rainfall.

Dhanaraj (1966) found a profound influence for rainfall on soil reaction. As rainfall increase there was a gradual decrease in the cation saturation. In the more humid zones leaching assumed significant proportions resulting in progressive increase in hydrogen ion concentration and prevalence of soil acidity.

IV Rainfall and nutrient status

a) Nitrogen

Alway *et al* (1916) noticed that in the loose soils of Nebraska nitrogen content was a linear function of the rainfall.

Sievers and Holtz (1923) demonstrated that in the soils of Washington the total nitrogen content increased with increase in altitude and rainfall.

In sub-tropical timber soils Jenny (1930) found that nitrogen content was not influenced by humidity factors. He found that it increased logarithmically with increase in N.S. quotient in grassland soils.

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

Dean (1937) found that nitrogen content increased with increase in rainfall.

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

From a study of 43 cultivated soil profiles distributed all over India Sen et al (1946) found no correlation between climate and nitrogen content.

Ray Chaudhuri (1957) found that both nitrogen and organic matter content increased with rainfall in the high altitude soils of India.

In a study of the effect of climate on the nitrogen content and organic matter reserves of Indian soils Jenny and Ray Chaudhuri (1958) found that these factors increased with increase in rainfall.

Harradine and Jenny (1958) found that generally soils were richer in nitrogen under conditions of increased precipitation.

Mutkar and Ray Chaudhuri (1959) found that in black and alluvial soils nitrogen increased with rainfall and N.S. quotient.

Unnikrishnan (1961), Mahalingam (1962) and Vijayachandran (1963) observed that nitrogen content increased with rainfall in the soils of Madras and Kerala.

Dhanaraj (1966) noted a close relationship between total nitrogen and rainfall in Mysore soils.

(b) Posphorus

Wohltmann (1901) found that the surface soils of Germany were some times richer and some times poorer in phosphates than the corresponding sub-soils.

Hopkins (1910) found in the prairie soils of Illinois and Iowa, a high percentage of phosphorus in the surface than in the sub-soils.

Ramann (1911) noticed that the distribution of phosphate in successive horizontal soil layers was not governed by any universal rule.

Alway and Islam (1916) observed that the proportion of phosphate was generally smaller in the first and second foot than in the lower layers.

In a study of 10 typical profiles of the major soil groups of Kerala Brito Muthunayagam and Koshy (1961) noted that the level of total phosphorus varied from 0.024 to 0.256%.

Aldrich and Buchanan (1954) observed that 60% of the South California soils examined by them had higher total phosphorus values in the first foot than in the second foot suggesting that rainfall associated with the downward movement of phosphorus was of minor importance in these soils.

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

Walker and Adams (1958), in their study of the organic matter of soils formed on similar parent material but under a range of climatic conditions, found that as rainfall increased the phosphorus content of organic matter tended to be lower.

Kanwar and Grewal (1959) found that the total reserves of native phosphorus are greater in the plains than in the hills where the soils are acidic.

Wild (1961), in a pedological study of phosphorus in 12 soils of Australia, found no correlation between loss of phosphorus and rainfall.

Nambiar (1963) in his study of the soil groups of Madras State observed that total phosphorus increased with rainfall significantly. Dhanaraj (1966) also made a similar observation with regard to Mysore soils.

(c) Potassium

Hilgard (1914) found that the relative migration and leaching of potassium in the soils was definitely more pronounced in humid regions with heavy rainfall than in the arid regions of scanty rainfall.

Sen et al (1949) revealed that lower values of potassium for Indian soils are only to be expected in view of the prevailing leaching conditions leading to laterisation in the humid tropics.

In a study of the vertical distribution of potassium in the soils of East Pakistan Karim and Khan (1956) found that this element decreased to a depth of 7" and thereafter increased progressively upto 36".

Dhanaraj (1966) found no correlation between potassium content and rainfall in the soils of Mysore.

(d) Calcium and magnesium

In a study of the Nebraska loess soils Alway (1916) found a pronounced negative correlation between annual precipitation and hydrochloric acid soluble calcium, as well as hydrochloric acid insoluble calcium.

Russel and Engle (1925) observed that the depth of the lime horizon increased with increasing rainfall in the soil horizons of the Central province of America.

In a study of certain soils of Eastern Washington Vlasoff et al (1937) found that the percentage of calcium in the soil colloids decreased and that of magnesium increased with increasing depth of the profiles.

Das et al (1946) found a high percentage of magnesium in the black type of soils of India. This element tended to increase with depth in the profiles studied.

Joshi et al (1960) showed that rainfall had a definite effect on the free lime content of the soil and the depth of lime accumulation zone in the soils of Kolhapur district.

(e) Organic matter and C/N ratio

Desaussure (1796) was of opinion that climate factors were responsible for the existence of different organic matter levels in soils.

Gmolick(1926) found that the chemical composition of humus was affected by climate. The amount of humus, however, remained unaffected by the climatic factor.

Craig and Halais (1934) pointed out that the organic matter content increased and the C/N ratio became wider with increase in precipitation in Mauritius soils.

In their investigations on the semiarid soils of Cape Province, Issoc and Gerhill (1936) found a slight increase in C/N ratio with increase in rainfall.

In Hawaiian soils Dean (1937) found that organic carbon increased with increasing nitrogen, rainfall and elevation.

In their study of Chinsura and Shahjahanpur soils of the humid regions Satyanarayana et al (1946) found that the carbon content was either steady or increased slightly within the first three feet and then decreased in the fourth foot. The C/N ratio of the brown soils in the humid zones increased in the second and third foot and narrowed down thereafter.

In an investigation of the chocolate soils of New South Wales Hallsworth et al (1952) found that the organic carbon content of the surface horizon increased with increasing rainfall.

Birch and Friend (1956) studied the organic matter status of East African soils and found that the main factor governing the organic matter and nitrogen content was rainfall.

Jenny and Raychaudhuri (1958) in their study of the effect of climate on the organic matter reserves of Indian soils observed that organic carbon increased with increase in rainfall.

Mutkar and Ray Chaudhuri (1959) noted that the organic carbon in black and alluvial soils increased with rainfall and N.S. quotient.

In a study of the C/N ratio of some Hawaiian soils Blomberg and Holmes (1959) found that organic carbon and nitrogen increased with rainfall.

In Alberta soils Synghal (1960) found that the carbon-nitrogen ratios were related to climate and that they increased progressively from the warm arid areas to the cooler more humid regions.

In his study of Indian laterite soils Unnikrishnan (1961) found a significant positive correlation between rainfall and organic carbon under humid conditions.

Mahalingam (1962) got a high positive correlation between loss on ignition and organic matter percentage of the soil and significant positive correlation between the percentages of organic carbon and nitrogen.

In his study of the major soil groups of Madras State Nambiar (1963) observed a close relationship between organic carbon and rainfall which he attributed to the direct effect of increased vegetation.

Vijayachandran (1963) found a significant positive correlation between rainfall and organic carbon in Kerala soils.

In the soils of Mysore State Dhanaraj (1966) found wide carbon-nitrogen ratios which showed a tendency to widen with increase in rainfall.

Premanathan and Durairaj (1966), in a study of 36 surface alluvial soils, found that there was a close relationship between organic carbon and ignition loss.

EFFECT OF ELEVATION ON SOIL PROPERTIES

Jenny (1941) stated that soil properties varied in the same direction with increasing altitude. Rotzer (1948) found that many soil properties altered regularly with variations in altitude.

I Physical properties

Costin *et al* (1952) observed a close relationship between elevation and mechanical composition in the Alpine humus soils of New South Wales. Stone and gravel were found to be a maximum at altitudes above 6000'. Coarse sand was a minimum at altitudes between 5500' and 6000'. Silt and clay were found to be a maximum between 5500' and 6000' which tended to decrease both with increase and decrease in the altitude.

II Chemical properties

Ray Chaudhuri and Mukerjee (1941) found that the silica content decreased significantly with increase in elevation in the laterite soils of India.

Ray Chaudhuri and Chakraborthy (1943) concluded that, so far as laterite soils were concerned, both annual rainfall and altitude above sea-level possessed significant negative correlation with silica-alumina ratio of the clay fraction.

In his study of Nilgiri soils Mahalingam (1962) indicated that the contents of iron oxide and aluminium oxide increased with elevation.

Dhanaraj (1966) found that high level laterites contain a relatively higher percentage of sesquioxide.

III Nutrient Status

a) Nitrogen

Sievers and Holtz (1923) have demonstrated that the nitrogen content of the soil increased with increase in altitude and rainfall.

Hocken Smith and Tucker (1933) studied the relationship between elevation and nitrogen content of grass land and forest soils in the rockey mountains of Colorado. They found that the nitrogen content of the soil increased with increase in elevation. Dean (1937) had also reported a similar relationship in Hawaiian soils.

Unnikrishnan (1961) and Mahalingam (1962) obtained a significant positive correlation between elevation and nitrogen content for Indian soils.

b) Organic Matter and C/N Ratio

Jensan (1929) found that C/N ratio increased with the increase in soil temperature.

Mclean (1930) obtained a higher C/N ratio for the soils of the tropics as compared to those of the temperate region

Dean (1937) found that the organic matter content of soils increased with increase in elevation. He also noted that elevation was inversly proportional to the mean annual temperature.

Retzer (1948) noticed an increase in organic matter content in the soils of Western Colorado with increaseing altitudes.

Costin et al (1952) found that the maximum organic matter content was obtained between 5000' and 6000' in the Alpine humus soils of South Wales. There was a fall in the organic matter content with decreasing elevation.

Jenny and Ray Chaudhuri (1958) observed a higher content of organic matter at higher elevations in their study of the effect of climate on the nitrogen and organic matter reserves of Indian Soils.

Unnikrishnan (1961) observed the inter-relationship between elevation and nitrogen in Indian laterite soils to be positive and significant.

Mahalingam (1962) found a positive correlation between elevation and the C/N ratio in the high level Nilgiri Soils.

In Mysore Soils, Dhanaraj (1966) found the relationship between organic carbon and elevation to be positive above an altitude of 500'.

MATERIALS AND METHODS

MATERIALS AND METHODS

The soils used in this study were collected from the High Ranges of Kerala situated in the Devikulam Taluk of Kottayam District. This is an interesting region both from the ecological and geological points of view. Though lying between 9° and 10° North latitudes, the average day temperature does not rise above 80°F even during mid-summer and between January and February the night temperature usually falls to 32°F with severe ground frosts. This unusual climatic conditions are mainly due to the elevation of the region and the characteristic configuration of the land which gives it a peculiar microclimate different from the surrounding place.

The main parent rock in this region is an archean igneous type rich in feldspars. Due to the rainfall ranging from 375 cm. to 625 cm. followed by three to four months of dry period there has been considerable laterisation and the resulting soil exhibits wide variations from argillaceous clay in the swamps to latosols of different colours, texture and composition in the uplands.

The total area of the High Ranges is 375 to 500 Sq.Km with a maximum width of 50 Km. from West to East and a length of 100 Km. from north to south. The rainfall drops significant from west to east. In Kalaar and Rajamalay the average rainfall is about 600 cm. per annum while 30 km. east of it the annual precipitation is less than 160 cm. showing a drop of 15 cm. for every Km. This variation in the rainfall is attributed to the peculiar topography of the land with numerous parallel Spurs across the main, north to south ridge of the Western Ghats.

Details of the soil samples collected

Soil profiles were taken from different elevations having varied rainfall. The places selected for taking profile pits were in the natural forests in the suburbs of the Kanan Devan Hills Produce Co. Ltd. Profiles were taken from elevations of 600, 900, 1200, 1500, 1800 and 2100 metres. Three profiles were taken from each elevation from spots separated by distances of 3-5 Km. Samples were collected from depths 0-15 Cm. 15-45 Cm. 45-75 Cm. and 75-105 Cm.

The general characteristics of the samples collected are given in Table I.

Analytical methods

The samples collected were dried in the shade, powdered gently and passed through a 2 mm. sieve. The material under the sieve was stored in stoppered bottles for subsequent analysis.

Determination of physical properties

a) The mechanical composition ofthe soil was determined by the international pipette method given by Sankaram (1966).

b) Apparent density, absolute specific gravity, maximum water holding capacity and porespace of the soils were determined by the Keen Raczkowski - box method as detailed by Sankaram (1966).

c) The pH of the soil was measured by using a Beckmann pH meter in a 1:2.5 soil water suspension.

Determination of chemical constitutents

a) Moisture

5 g. of the soil was taken in a weighing bottle and dried in an air oven at 105°C to constant weight. The difference in weight was noted and expressed as percentage on oven dry basis (Sankaram 1966).

b) Loss on ignition

10 g. of the soil was ignited at dull red heat in a muffle furnace and the loss in weight determined and expressed as percentage on oven dry basis (Sankaram 1966).

c) Analysis of hydrochloric acid extract

20 g. of the soil was digested with 6.75:3.25 hydrochloric acid on a sand bath for 2 hours and allowed to

settle over night. The extract was collected and made upto 500 ml. In the Hcl extract the following estimations were made.

(i) Phosphorus

An aliquot of the Hcl extract was evaported to dryness. 10 ml. of concentrated nitric acid was added and the contents evaported. The process of adding HNO_3 and drying was repeated 3 or 4 times till the dried residue showed a granular appearance. The residue was extracted with dil Hcl and phosphorus estimated in the filtrate by precipitating as ammonium phosphomolybdate as in the method described by Jackson (1958). The residue was expressed as acid soluble silica.

(ii) Potassium

An aliquot of the acid extract was taken in a silica dish, evaporated to dryness and the residue ignited. The hot water extract of the residue was taken and K_2O estimated volumetrically by Volk's cobaltinitrite method as given by Piper (1950).

(iii) Sesqui-oxides

The sesqui-oxides were precipitated in 50 ml. of the acid extract using excess ammonium hydroxide. The residue was ignited and weighed and expressed as percentage as in the method given by Sankaram (1966).

(iv) Calcium and magnesium

The filtrate after separating the sesqui-oxides was made upto a known volume. In appropriate aliquotes calcium and magnesium were estimated by the versenate method as given by Sankaram (1966).

d) Nitrogen

This was estimated by the Kjeldahl method (Piper 1950).

e) Organic carbon

This was estimated by Walkley and Black's method as given by Piper (1950).

Separation of clay and analysis of clay fraction

The clay was separated by the method detailed by Piper (1950)

The fusion extract of the clay was prepared by the method described by Sankaram (1966).

In the fusion extract the silica, sesqui oxides, and aluminium oxides were estimated by the methods given by Piper (1950).

Statistical Analysis

Simple correlations were worked out between different soil characeristics from the analytical data.

Table I

General Characteristics of the Soils

Location	Profile and Depth	Gravel %	Colour	Texture
Anachal	Profile I			
600 metres	0-15 cm.	10.6	2.5 YR 3/6	Clay
	15-45 cm.	10.7	2.5 YR 4/8	Clay
	45-75 cm.	11.3	2.5 YR 4/8	Clay
	75-105cm.	12.6	2.5 YR 4/6	Clay
	Profile II			
	0-15 cm.	10.9	7.5 YR 3/2	Clay
	15-45 cm.	3.4	5 YR 2/1	Clay
	45-75 cm.	3.6	7.5 YR 2/0	Clay
	75-105cm.	3.6	5 YR 3/2	Clay
	Profile III			
	0-15 cm.	3.6	10 YR 3/1	Clay
	15-45 cm.	1.2	7.5 YR 3/2	Clay
	45-75 cm.	7.0	7.5 YR 4/2	Clay
	75-105cm.	14.6	7.5 YR 4/4	Clay

(Contd..)

Table 1

General Characteristics of the Soils

Location	Profile and Depth	Gravel %	Colour	Texture
	Profile I			
Chithirapuram 900 metres	0-15 cm.	9.6	7.5 YR 3/2	Clay
	15-45 cm.	16.1	7.5 YR 4/4	Clay
	45-75 cm.	7.5	5 YR 5/8	Clay
	75-105cm.	9.3	5 YR 5/8	Clay
	Profile II			
	0-15 cm.	7.8	5 YR 3/3	Clay
	15-45 cm.	14.6	5 YR 3/4	Clay
	45-75 cm.	14.5	5 YR 4/8	Clay
	75-105cm.	14.3	5 YR 4/8	Clay
	Profile III			
	0-15 cm.	13.9	5 YR 3/2	Clay
	15-45 cm.	8.4	5 YR 4/6	Clay
	45-75 cm.	5.7	5 YR 4/8	Clay
	75-105cm.	4.8	5 YR 4/6	Clay

(Contd..)

Table I

General Characteristics of the Soils

Location	Profile and Depth	Gravel %	Colour	Texture
	Profile I			
Kalaar				
1200 metres	0-15 cm.	20.4	7.5 YR 7/2	Clay loam
	15-45 cm.	14.2	7.5 YR 8/2	loam
	45-75 cm.	14.6	7.5 YR 8/2	loam
	75-105cm.	18.3	7.5 YR 8/4	Silty loam
	Profile II			
	0-15 cm.	22.2	5 YR 4/6	Clay loam
	15-45 cm.	33.0	5 YR 6/6	Loam
	45-75 cm.	30.7	5 YR 6/6	loam
	75-105cm.	17.3	5 YR 6/4	Silty clay loam
	Profile III			
	0-15 cm.	21.9	7.5 YR 6/4	Clay loam
	15-45 cm.	14.9	5 YR 6/8	loam
	45-75 cm.	24.3	5 YR 6/8	loam
	75-105cm.	10.8	5 YR 7/4	Silty clay loam.

(Contd..)

Table I

General Characteristics of the Soils

Location	Profile and Depth	Gravel %	Colour	Texture
	Profile I			
Nullatani 1500 metres	0-15 cm.	11.1	5 YR 3/3	Silty loam
	15-45 cm.	10.6	5 YR 3/4	Silty loam
	45-75 cm.	15.9	5 YR 4/4	Silty loam
	75-105cm.	33.3	5 YR 4/4	Silty loam
	Profile II			
	0-15 cm	17.7	5 YR 4/6	Silty clay
	15-45 cm	17.7	5 YR 4/8	Silty clay
	45-75 cm.	12.8	5 YR 5/6	Clay loam
	75-105 cm.	7.9	5 YR 4/8	Clay loam
	Profile III			
	0-15 cm.	13.7	5 YR 3/4	Silty clay
	15-45 cm.	4.5	5 YR 3/2	Silty clay
	45-75 cm.	4.5	5 YR 2/2	Clay loam
	75-105 cm.	7.7	5 YR 3/2	Clay loam

(Contd..)

Table I

General Characteristics of the Soil

Location	Profile and Depth	Gravel %	Colour	Texture
	Profile I			
Rajamalay				
1800 metres	0-15 cm.	0.0	5 YR 3/2	Clay
	15-45 cm.	4.3	5 YR 3/4	Silty clay
	45-75 cm.	13.4	5 YR 3/3	Clay
	75-105 cm.	7.3	7.5 YR 4/4	Clay
	Profile II			
	0-15 cm.	3.9	5 YR 3/2	Clay
	15-45 cm.	2.0	5 YR 3/1	Clay
	45-75 cm.	22.6	5 YR 3/2	Clay
	75-105 cm.	11.3	2.6 YR 3/6	Clay
	Profile III			
	0- 15 cm.	26.5	5 YR 4/6	Clay
	15-45 cm.	19.2	2.5 YR 3/6	Clay
	45-75 cm.	15.0	2.5 YR 3/4	Silty clay
	75-105 cm.	13.2	2.5 YR 3/4	Clay

(Contd..)

Table I

General Characteristics of the Soils

Location	Profile and Depth	Gravel %	Colour	Texture
	Profile I			
Kajemalay				
2100 metres	0-15 cm.	7.9	5 YR 2/2	Clay
	15-45 cm.	5.1	5 YR 4/2	Clay
	45-75 cm.	20.1	7.5 YR 4/4	Clay loam
	75-105 cm.	20.9	7.5 YR 5/6	Clay
	Profile II			
	0-15 cm.	7.6	7.5 YR 4/4	Clay
	15-45 cm.	10.5	7.5 YR 4/4	Clay
	45-75 cm.	32.3	5 YR 4/4	Clay
	75-105 cm.	18.1	5 YR 4/8	Clay
	Profile III			
	0-15 cm.	11.3	5 YR 3/3	Clay
	15-45 cm.	21.1	5 YR 4/8	Clay
	45-75 cm.	11.6	5 YR 6/8	Clay
	75-105 cm.	30.4	5 YR 5/8	Clay

RESULTS

RESULTS

I. Physical properties

(1) Mechanical analysis

The results of the mechanical analysis of the soils are given in Tables II to VII and represented graphically in Fig. I.

The highest percentage of coarse sand was found in soils collected from an elevation of 1200 metres (47.5%) and the lowest value (9.6%) was obtained in soils collected from an altitude of 1800 metres. The percentage of fine sand was highest in the soils developed at an elevation of 1200 metres (28.6%) and was lowest in the soils developed at an altitude of 1800 metres (2.2%). The silt fraction showed the maximum value in the soils at 1200 metres' elevation (34.4%) and the lowest was found in soils from 600 metres' elevation (3.2%). The clay content ranged from 14.7% in the soils at 1200 metres to 64.0% in the soils at 1800 metres.

The content of coarse sand increased with increase in depth at all elevations except in the soils formed at 1800

TABLE II

Mechanical Analysis of the soils collected from elevation 600 metres and rainfall 325 cm.

Profile and	Depth (Cm.)	Coarse sand %	Fine sand %	Silt %	Clay %	Organic matter %
Profile I	0-15	27.8	10.7	3.2	52.4	3.9
	15-45	36.4	12.6	3.8	46.9	1.4
	45-75	38.7	11.3	5.7	42.6	1.7
	75-105	37.8	12.0	5.5	42.5	2.2
Profile II	0-15	28.4	13.2	6.0	45.5	6.9
	15-45	33.3	14.9	4.3	40.5	7.0
	45-75	35.9	14.3	4.9	37.7	7.2
	75-105	37.5	14.1	6.3	35.2	6.9
Profile III	0-15	25.6	5.8	10.5	53.9	4.2
	15-45	30.5	7.6	11.1	47.3	3.5
	45-75	35.3	7.1	12.9	42.7	2.0
	75-105	35.7	8.6	12.9	41.8	1.0
Mean of all Profiles	0-15	27.3	9.9	6.6	50.6	5.0
	15-45	33.1	11.7	6.4	44.9	3.9
	45-75	36.6	10.9	7.8	41.0	3.6
	75-105	37.0	11.5	8.2	39.8	3.4
Mean of all Depths						
Profile I		34.9	11.6	4.5	46.1	2.3
Profile II		33.8	14.1	5.4	39.7	7.0
Profile III		31.8	7.2	11.8	46.4	2.7

TABLE III

Mechanical Analysis of the soils collected from elevation 900 metres and rainfall 425 cm.

Profile and Depth (Cm.)		Coarse sand %	Fine sand %	Silt %	Clay %	Organic matter %
Profile I	0-15	24.9	15.9	4.5	51.0	3.7
	15-45	26.3	14.0	5.0	52.5	2.2
	45-75	27.6	13.3	5.7	51.6	1.8
	75-105	29.3	12.6	6.0	50.2	1.9
Profile II	0-15	26.5	13.6	6.7	47.3	5.9
	15-45	28.3	12.6	8.3	47.7	3.1
	45-75	25.5	7.9	8.9	54.3	3.2
	75-105	31.9	14.7	9.2	41.1	3.1
Profile III	0-15	20.5	10.9	114	54.1	3.1
	15-45	21.8	9.6	12.1	55.3	1.2
	45-75	22.5	8.9	12.8	54.7	1.1
	75-105	24.7	8.2	13.0	53.1	1.0
Mean of all profiles	0-15	23.9	13.4	7.5	50.8	4.2
	15-45	25.5	12.1	8.5	51.8	2.2
	45-75	25.2	10.0	9.1	53.6	2.0
	75-105	28.6	11.8	9.4	48.1	2.0
Mean of all Depths						
Profile I		27.0	13.9	5.3	51.3	2.4
Profile II		28.1	12.2	8.3	47.6	3.8
Profile III		22.4	9.4	12.3	54.3	1.6

TABLE IV

Mechanical Analysis of the soils collected from elevation 1200 metres and rainfall 625 cm.

Profile and Depth (Cm.)		Coarse sand %	Fine sand %	Silt %	Clay %	Organic matter %
Profile I	0-15	41.7	21.5	10.5	25.6	0.7
	15-45	47.0	28.6	9.4	14.7	0.3
	45-75	43.1	22.9	16.5	17.3	0.2
	75.105	27.3	21.6	34.4	16.5	0.2
Profile II	0-15	41.9	23.4	9.2	22.9	2.6
	15-45	47.5	23.6	10.3	17.6	1.0
	45-75	40.3	20.7	15.5	22.6	0.9
	75-105	22.9	18.5	20.3	30.6	0.8
Profile III	0-15	37.5	16.4	15.5	28.8	1.8
	15-45	45.0	20.5	14.4	19.6	0.5
	45-75	38.4	18.7	21.5	20.9	0.5
	75-105	22.0	17.8	30.2	29.5	0.5
Mean of all Profiles						
	0-15	40.4	20.4	11.7	25.8	1.7
	15.45	46.5	24.2	11.4	17.3	0.6
	45-75	40.6	20.8	17.8	20.2	0.5
	75-105	24.1	19.3	28.3	25.5	0.5
Mean of all Depths						
Profile I		39.8	23.6	17.7	18.5	0.3
Profile II		38.1	21.5	13.8	23.4	1.3
Profile III		35.7	18.3	20.4	24.7	0.8

TABLE V

Mechanical Analysis of the soils collected from elevation 1500 metres and rainfall 535 Cm.

Profile and Depth (Cm.)		Coarse sand %	Fine sand %	Silt %	Clay %	Organic matter %
Profile I	0-15	10.9	3.4	19.5	60.2	5.0
	15-45	11.5	2.2	18.4	64.0	3.9
	45-75	30.3	22.8	12.5	21.4	4.0
	75-105	30.0	19.1	15.0	32.0	3.9
Profile II	0-15	9.6	4.4	20.3	58.8	6.9
	15-45	10.2	4.1	19.2	61.8	4.7
	45-75	30.1	25.7	15.5	24.9	3.8
	75-105	25.3	20.7	15.3	36.7	2.0
Profile III	0-15	15.1	8.5	18.2	54.5	3.7
	15-45	16.5	7.2	17.5	56.5	2.3
	45-75	30.2	16.9	15.1	35.8	2.0
	75-105	28.1	17.4	18.2	36.1	0.2
Mean of all profiles						
	0-15	11.9	5.4	19.3	57.8	5.2
	15-45	12.7	4.5	18.4	60.8	3.6
	45-75	33.2	21.8	14.4	27.4	3.2
	75-105	27.8	19.1	16.2	34.9	2.0
Mean of all Depths						
Profile I		22.9	11.9	16.3	44.4	4.2
Profile II		18.8	13.7	17.6	45.5	4.4
Profile III		22.5	12.5	17.2	45.7	2.1

TABLE VI

Mechanical Analysis of the soils collected from elevation 1800 metres and rainfall 540 Cm.

Profile and Depth (Cm.)		Coarse sand %	Fine sand %	Silt %	Clay %	Organic matter %
Profile I	0-15	27.9	5.9	16.5	45.6	5.1
	15-45	12.6	2.8	24.3	54.6	3.7
	45-75	21.9	4.3	16.2	55.1	2.5
	75-105	34.4	6.1	10.6	47.1	1.8
Profile II	0-15	20.4	9.2	13.5	48.9	8.0
	15-45	17.6	7.6	18.1	53.3	3.4
	45-75	20.5	6.9	19.5	50.0	3.1
	75-105	30.2	5.2	16.3	46.4	2.9
Profile III	0-15	22.3	10.4	14.7	49.7	2.9
	15-45	16.6	8.9	23.3	51.0	0.2
	45-75	18.9	10.3	21.0	49.5	0.3
	75-105	30.6	12.6	15.2	41.3	0.3
Mean of all profiles	0-15	23.5	8.5	14.6	48.1	5.3
	15-45	15.6	6.4	21.9	52.9	2.4
	45-75	20.4	7.2	18.9	51.2	2.0
	75-105	31.7	7.9	14.0	44.6	1.7
Mean of all Depths						
Profile I		24.2	4.8	16.6	50.6	3.3
Profile II		22.2	7.2	16.8	49.4	4.3
Profile III		22.1	10.5	18.5	47.9	0.9

TABLE VII

Mechanical Analysis of the soils collected from elevation 2100 metres and rainfall 550 cm.

Profile and Depth (Cm.)		Coarse sand %	Fine sand %	Silt %	Clay %	Organic matter %
Profile I	0-15	12.2	6.3	18.4	58.2	4.9
	15-45	23.6	6.2	11.0	55.4	4.8
	45-75	44.7	16.7	5.0	32.7	0.9
	75-105	35.2	11.0	9.5	43.4	0.9
Profile II	0-15	17.4	6.5	17.3	49.4	9.4
	15-45	20.5	4.9	10.3	59.1	5.2
	45-75	30.1	15.5	9.0	40.9	4.5
	75-105	32.5	14.1	6.5	43.7	3.2
Profile III	0-15	18.9	10.9	17.4	49.3	3.6
	15-45	22.6	7.4	12.9	56.3	0.8
	45-75	32.3	19.1	10.2	38.0	0.4
	75-105	30.1	12.9	8.3	48.0	0.7
Mean of all profiles	0-15	16.2	7.9	17.7	52.3	5.9
	15-45	22.2	5.8	11.4	56.9	3.6
	45-75	35.7	17.1	8.1	37.2	1.9
	75-105	32.9	12.6	8.1	45.0	1.6
Mean of all Depths						
Profile I		28.9	9.8	10.9	47.4	2.9
Profile II		25.1	10.2	10.8	48.3	5.6
Profile III		25.9	12.6	12.2	47.9	1.3

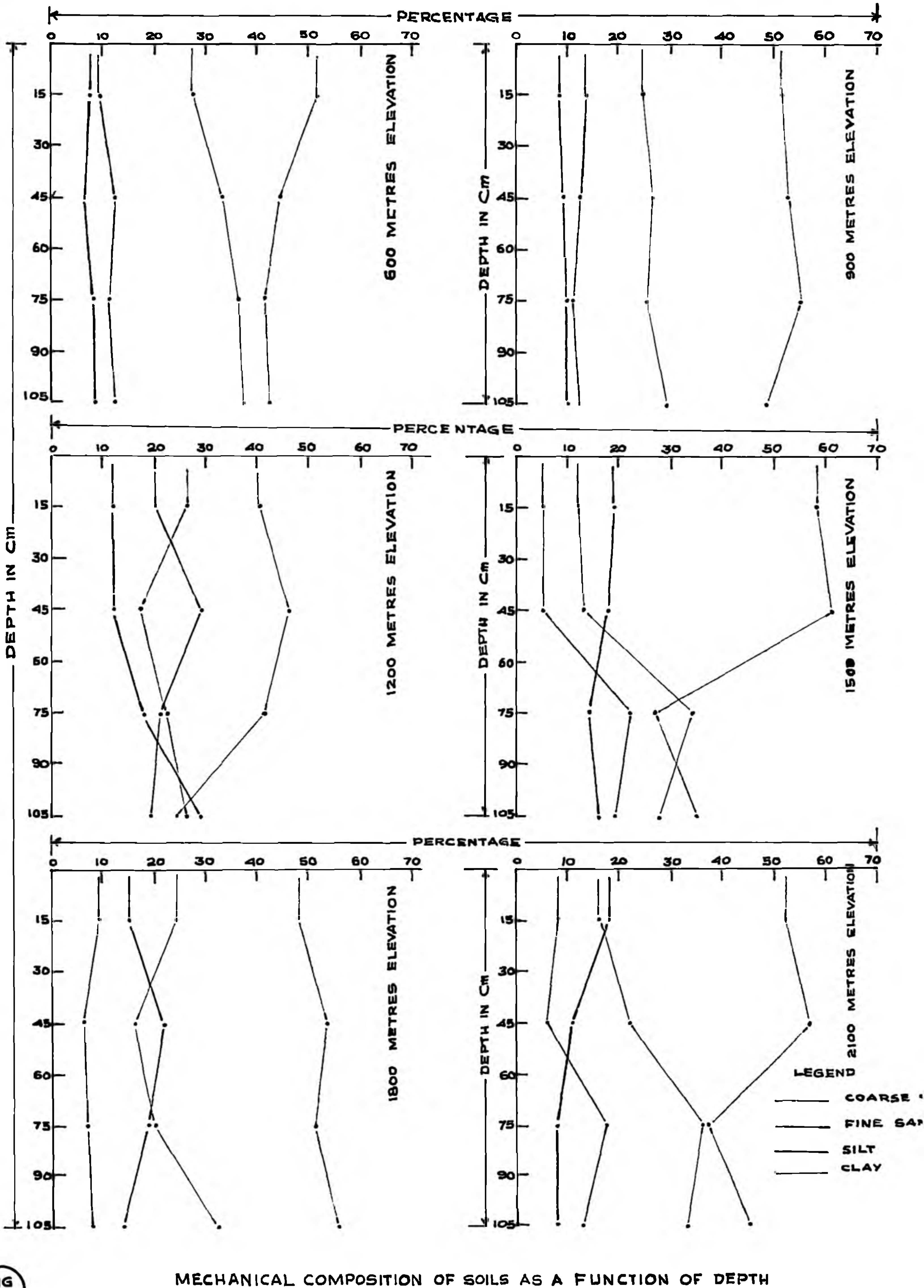


FIG 1

MECHANICAL COMPOSITION OF SOILS AS A FUNCTION OF DEPTH

TABLE VIII

Single value constants of the soils collected from elevation 600 metres and rainfall 325 cm.

Profile and depth(Cm)		Apparent density	Absolute specific gravity	Maximum water holding capacity %	Pore-space %
Profile I	0-15	1.21	2.39	41.93	49.31
	15-45	1.41	2.64	33.01	46.59
	45-75	1.35	2.58	35.34	47.77
	75-105	1.41	2.59	30.98	43.87
Profile II	0-15	1.25	2.43	42.16	49.74
	15-45	1.46	2.68	34.52	48.25
	45-75	1.38	2.63	36.14	49.12
	75-105	1.44	2.65	31.25	46.55
Profile III	0-15	1.23	2.47	41.65	44.96
	15-45	1.32	2.69	32.14	45.24
	45-75	1.35	2.65	35.24	44.26
	75-105	1.42	2.62	28.56	40.94
Mean of all profiles					
	0-15	1.13	2.43	41.91	48.00
	15-45	1.39	2.67	33.22	46.69
	45-75	1.36	2.62	35.57	47.05
	75-105	1.42	2.62	30.26	43.45
Mean of all Depths					
Profile I		1.35	2.55	35.32	46.88
Profile II		1.38	2.60	36.02	48.16
Profile III		1.33	2.61	34.39	43.85

TABLE IX

Single value constants of the soils collected from elevation 900 metres and rainfall 425 cm.

Profile and Depth (Cm.)		Apparent density	Absolute specific gravity	Maximum water holding %	Pore-space %
Profile I	0-15	1.14	2.43	46.67	53.17
	15-45	1.24	2.54	41.20	41.84
	45-75	1.32	2.67	38.26	38.26
	75-105	1.33	2.70	38.40	39.14
Profile II	0-15	1-12	2.40	45.46	52.76
	15-45	1.22	2.52	40.29	40.25
	45-75	1.31	2.61	37.14	37.52
	75-105	1.34	2.65	37.25	38.46
Profile III	0-15	1.18	2.45	44.22	46.86
	15-45	1.24	2.56	39.54	40.24
	45-75	1.35	2.64	36.14	39.14
	75-105	1.37	2.72	36.56	40.25
Mean of all profiles					
	0-15	1.15	2.43	45.41	60.96
	15-45	1.23	2.54	40.34	40.77
	45-75	1.33	2.64	37.18	38.31
	75-105	1.34	2.69	37.43	39.28
Mean of all Depths :					
Profile I		1.26	2.58	41.13	43.10
Profile II		1.25	2.54	40.06	42.25
Profile III		1.28	2.59	39.11	41.64

TABLE X

Single value constant of the soils collected from elevation 1200 metres and rainfall 625 cm.

Profile and Depth(Cm)		Apparent Density	Absolute specific gravity	Maximum water holding capacity %	Pore-space %
Profile I	0-15	1.25	2.51	37.10	49.13
	15-45	1.34	2.57	35,33	35.33
	45-75	1.28	2.48	30.55	38.55
	75-105	1.16	2.54	36.84	47.83
Profile II	0-15	1.24	2.48	38.15	50.25
	15-45	1.31	2.49	36.44	36.54
	45-75	1.25	2.47	31.12	39.72
	75-105	1.12	2.51	37.54	48.92
Profile III	0-15	1.26	2.52	35.45	46.24
	15-45	1.34	2.56	33.92	36.25
	45-75	1.27	2.58	30.36	39.46
	75-105	1.24	2.65	31.96	44.34
<u>Mean of all profiles</u>	0-15	1.25	2.50	36.90	48.54
	15-45	1.33	2.54	35.23	37.04
	46-75	1.26	2.51	30.67	37.24
	75-105	1.17	2.57	35.44	46.99
<u>Mean of all Depths</u>					
Profile I		1.26	2.52	34.95	42.71
Profile II		1.23	2.49	35.81	43.85
Profile III		1.28	2.58	32.92	41.55

TABLE XI

Single value constants of the soil collected from elevation 1500 metres and rainfall 535 cm.

Profile and Depth(Cm.)		Apparent Density	Absolute specific gravity	Maximum water holding capacity %	Pore-space %
Profile I	0-15	1.02	2.15	46.68	47.82
	15-45	1.09	2.17	45.08	46.30
	45-75	1.21	2.31	40.29	40.37
	75-105	1.32	2.32	32.19	43.06
Profile II	0-15	1.02	2.18	45-68	48.64
	15-45	1.11	2.20	44.24	46.82
	45-75	1.20	2.32	40.12	44.14
	75-105	1.35	2.35	30.18	42.18
Profile III	0-15	1.12	2.26	44.62	45.26
	15-45	1.15	2.28	43.82	44.04
	45-75	1.18	2.32	40.12	42.57
	75.105	1.24	2.35	33.16	35.92
<u>Mean of all profiles</u>					
	0-15	1.06	2.19	45.66	47.24
	15-45	1.12	2.22	44.38	45.69
	45-75	1.21	2.32	40.18	43.36
	75-105	1.30	2.34	31.84	40.39
<u>Mean of all Depths</u>					
Profiles I		1.16	2.24	41.06	45.11
Profiles II		1.18	2.26	40.05	45.44
Profiles III		1.17	2.30	40.43	41.94

TABLE XII

Single value constant of the soils collected from elevation 1800 metres and rainfall 640 cm.

Profiles and Depth (Cm.)		Apparent density	Absolute specific gravity	Maximum water holding capacity %	Pore-space %
Profile	0-15	1.14	2.19	42.29	45.49
	15-45	1.22	2.24	37.68	38.26
	45-75	1.35	2.28	32.63	35.15
	75-105	1.47	2.35	24.71	24.71
Profile II	0-15	1.05	2.08	43.12	46.42
	15-45	1.18	2.21	38.24	40.29
	45-75	1.31	2.22	33.84	36.12
	75-105	1.38	2.24	25.24	26.15
Profile III	0-15	1.02	2.15	40.25	42.56
	15-45	1.11	2.18	38.51	40.24
	45-75	1.18	2.28	31.24	33.96
	75-105	1.32	2.35	23.81	26.25
<u>Mean of all profiles</u>					
	0-15	1.07	2.14	41.88	44.82
	15-45	1.17	2.21	38.14	39.59
	45-75	1.28	2.26	32.67	34.74
	75-105	1.39	2.30	24.59	25.70
<u>Mean of all Depths</u>					
Profile I		1.29	2.26	34.33	35.90
Profile II		1.23	2.19	35.11	37.24
Profile III		1.16	2.24	33.45	35.75

TABLE XIII

Single value constants of the soils collected from elevation 2100 metres and rainfall 550 cm.

Profile and depth (Cm.)		Apparent density	Absolute specific gravity	Maximum water holding capacity %	Pore-space %
Profile I	0-15	1.25	2.12	40.26	41.12
	15-45	1.27	2.08	35.28	39.49
	45-75	1.29	2.05	28.31	28.31
	75-105	1.34	2.10	26.80	26.80
Profile II	0-15	1.22	2.04	42.25	45.12
	15-45	1.24	2.02	36.14	38.24
	45-75	1.25	2.01	29.25	30.54
	75-105	1.28	2.03	27.94	28.45
Profile III	0-15	1.28	2.12	39.61	42.94
	15-45	1.32	2.18	34.32	38.65
	45-75	1.36	2.27	27.62	29.94
	75-105	1.38	2.35	24.21	26.46
Mean of all profiles	0-15	1.25	2.09	40.67	43.06
	15-45	1.28	2.09	35.24	38.79
	45-75	1.29	2.11	28.36	29.59
	75-105	1.33	2.16	23.65	27.24
Mean of all Depth					
Profile I		1.29	2.09	32.66	33.93
Profile II		1.25	2.03	33.89	35.69
Profile III		1.33	2.23	31.39	34.49

metres. At lower elevations the surface horizons generally contained a higher proportion of clay but at higher altitudes the clay content was more in the lower horizons.

(2) Single value constants

The single value constants of the soils are given in Tables VIII to XIII.

(a) Apparent density

The apparent density of the soils increased with depth in all the profiles except those collected from elevations of 600-1200 metres. The lowest value (1.02) was in the soils formed at 1200 metres and the highest value (1.47) was in the soils from 1800 metres' elevation.

(b) Absolute specific gravity

The absolute specific gravity increased with increase in depth in the soils at elevations from 900-2100 metres. The lowest value obtained was 2.02 in the soils from 2100 metres and highest value found was 2.72 in the soils at 900 metres' elevation. The absolute specific gravity generally increased with increase in elevation except at 600 metres and 1200 metres.

(c) Maximum water-holding capacity

The maximum water-holding capacity of the soils varied from 24.7% in the soils at 1800 metres to 46.7% in the soils at 1600 metres. In the surface samples the maximum water holding capacity was 46.7% found in the soils at 1600 metres and the minimum value was 37.1% in the soils at 1200 metres.

(d) Pore space

The maximum pore space obtained was 53.2% in the soils formed at 300 metres and it decreased to 24.7% in the soils from 1800 metres.

3. Moisture

The moisture content of the samples is given in Tables XIV to XIX. It varied from 1.07% in the soils formed at 1200 metres to 13.0% in the soils at 2100 metres. At all elevations the moisture percentage showed a steady decrease with depth in all profiles.

4. Loss on ignition

The loss on ignition of the soils is given in the Tables XIV to XIX. The highest value, viz., 35.4% was found in the soils at the elevation of 1800 metres. The soils at 1200 metres showed the lowest percentage of loss on ignition (3.8%). The loss on ignition showed a decrease down the profile at all elevations.

TABLE XIV

<u>pH, Moisture and Loss on Ignition of the soils collected from elevation 600 metres and rainfall 325 cm.</u>

Profile and depth (Cm.)		pH	Moisture %	Loss on Ignition %
Profile I	0-15	5.4	7.58	15.68
	15-45	6.4	4.13	13.54
	45-75	5.7	3.96	12.84
	75-105	5.5	3.52	12.04
Profile II	0-15	5.6	6.42	14.62
	15-45	5.0	4.86	13.56
	45-75	4.5	4.12	11.93
	75-105	4.5	3.82	11.12
Profile III	0-15	5.5	8.53	16.42
	15-45	5.4	5.26	15.25
	45-75	5.2	4.92	13.52
	75-105	5.0	4.16	12.96
<u>Mean of all profiles</u>	0-15	5.5	7.51	15.57
	16-45	5.2	4.75	14.12
	45-75	5.1	4.33	12.76
	75.105	5.0	3.83	12.04
<u>Mean of all depths</u>				
Profile I		5.5	4.79	13.52
Profile II		5.1	4.80	12.81
Profile III		5.3	5.71	14.63

TABLE XV

pH, Moisture and Loss on Ignition of the soils collected from elevation 900 metres and rainfall 425 cm.

Profile and Depth (Cm.)		pH	Moisture %	Loss on Ignition %
Profile I	0-15	5.3	8.72	17.96
	15-45	5.5	8.10	15.06
	45-75	5.3	6.60	13.58
	75-105	5.5	6.00	10.26
Profile II	0-15	4.7	9.12	18.65
	15-45	5.0	8.71	15.56
	45-75	5.0	7.26	12.92
	75-105	4.9	6.82	11.02
Profile III	0-15	5.2	9.42	17.25
	15-45	5.1	8.86	14.96
	45-75	5.1	7.35	12.82
	75-105	5.1	6.72	10.89
Mean of all profiles	0-15	5.0	9.08	17.95
	15-45	5.1	8.56	15.19
	45-75	5.1	7.07	13.11
	75-105	5.1	6.51	10.72
Mean of all Depths				
Profile I		5.3	7.35	14.21
Profile II		4.9	7.98	14.54
Profile III		5.1	8.09	13.98

TABLE XVI

pH, Moisture and Loss on Ignition of the soils collected from elevation 1200 metres and rainfall 625 cm.

Profile and Depth (Cm.)		pH	Moisture %	Loss on Ignition %
Profile I	0-15	5.4	3.98	13.20
	15-45	5.6	2.16	7.90
	45-75	5.5	2.02	4.16
	75-105	5.3	1.07	3.80
Profile II	0-15	4.5	4.92	14.26
	15-45	4.5	2.56	9 .62
	45-75	4.4	2.12	7.52
	75-105	4.4	1.62	4.16
Profile III	0-15	5.0	12.26	15.52
	15-45	4.9	10.12	7.85
	45-75	4.7	7.59	3.75
	75-105	4.5	6.42	2.92
Mean of all profiles				
	0-15	4.9	7.05	13.32
	15-45	5.0	4.94	8.42
	45-75	4.9	3.91	5.14
	75-105	4.7	3.04	3.62
Mean of all depths				
Profile I		5.4	2.31	7.26
Profile II		4.4	2.80	8.86
Profile III		4.8	9.09	6.76

TABLE XVII

pH, Moisture and Loss on Ignition of the Soils collected from elevation 1500 metres and rainfall 535 cm.

Profile and Depth (Cm.)		pH	Moisture %	Loss on Ignition %
Profile I	0-15	5.2	11.23	30.70
	15-45	5.4	9.81	27.86
	45-75	5.4	8.75	22.06
	75-105	5.7	7.24	17.44
Profile II	0-15	4.7	12.52	29.73
	15-45	4.9	10.21	26.25
	45-75	5.3	9.02	21.57
	75-105	5.4	7.53	16.24
Profile III	0-15	5.3	13.26	31.75
	15-45	5.4	11.45	28.24
	45-75	5.5	10.21	23.02
	75-105	5.6	8.54	17.52
Mean of all profiles	0-15	5.1	12.35	30.73
	15-45	5.2	10.40	27.45
	45-75	5.4	9.32	22.22
	75-105	5.5	7.77	17.06
Mean of all Depths				
Profile I		5.4	9.27	24.21
Profile II		5.1	9.82	23.44
Profile III		5.2	10.86	25.13

TABLE XVIII

pH, Moisture and Loss on Ignition of the soils collected from elevation 1800 metres and rainfall 540 cm.

Profiles and Depth (Cm.)		pH	Moisture %	Loss on Ignition %
Profile I	0-15	5.0	12.32	35.44
	15-45	5.0	8.93	23.66
	45-75	5.5	8.23	13.90
	75-105	5.5	7.42	12.30
Profile II	0-15	5.4	13.53	32.94
	15-45	5.5	9.35	21.37
	45-75	5.7	8.96	10.24
	75-105	5.8	7.75	9.56
Profile III	0-15	5.2	12.24	33.03
	15-45	5.3	9.16	23.94
	45-75	5.3	8.25	13.72
	75-105	5.4	7.16	11.95
Mean of all profiles				
	0-15	5.2	12.99	33.80
	15-45	5.3	9.14	22.99
	45-75	5.5	8.48	12.62
	75-105	5.6	7.44	11.27
Mean of all Depths				
Profile I		5.2	9.22	21.32
Profile II		5.6	9.89	18.52
Profile III		5.3	9.20	20.66

TABLE XIX

pH, Moisture and Loss on Ignition of the soils collected from 2100 metres elevation and rainfall 560 cm.

Profiles and Depth(Cm.)		pH	Moisture %	Loss on Ignition %
Profile I	0-15	5.5	13.87	28.54
	15-45	5.6	9.56	20.08
	45-75	5.8	8.73	19.68
	75-105	5.6	7.56	9.58
Profile II	0-15	5.3	12.93	26.54
	15-45	6.3	8.32	20.21
	45-75	6.4	7.25	19.56
	75-105	6.4	6.12	8.94
Profile III	0-15	5.2	13.52	27.53
	15-45	5.4	9.24	20.26
	45-75	5.6	8.12	18.54
	75-105	6.0	7.06	8.25
Mean of all profiles				
	0-15	5.3	13.44	27.63
	15-45	5.7	9.04	20.18
	45-75	5.9	8.03	19.26
	75-105	6.0	6.91	8.92
Mean of all Depths				
Profile I		5.6	9.93	19.47
Profile II		6.1	8.65	18.81
Profile III		5.5	9.48	24.86

There was significant negative correlation (r= -0.647) between loss on ignition and the sand content and positive correlation (r= +0.541) between this property and clay content.

II. Chemical properties

The chemical properties of the soils are presented in Tables XIV to XXXVII.

(i) Soil reaction

The pH of the soil (Tables XV to XIX) varied from 4.8 in the soils at 1200 metres to 6.4 in the soils at 2100 metres.

(ii) Organic carbon

The organic carbon content of the soils (Tables XX to XXV) was found to vary from 0.14% at 1200 metres to 5.46% at 2100 metres. It decreased steadily with depth in all the profiles at all elevations.

The relationship between organic carbon and sand content of the soils was negative (r = -0.634) but a positive correlation existed between organic carbon and clay content (r = +0.382), as well as between organic carbon and water holding cpacity (r = +0.339).

TABLE XX

Carbon, Nitrogen and C/N ratio of the soils collected from elevation 600 metres and rainfall 326 cm.

Profiles and depth (Cm.)		Carbon %	Nitrogen %	C/N Ratio
Profile I	0-15	1.268	0.114	11.1
	15-45	0.806	0.080	10.1
	45-75	0.965	0.065	14.8
	75-105	0.868	0.065	13.3
Profile II	0-15	4.010	0.262	15.3
	15-45	4.051	0.174	23.2
	45-75	4.040	0.229	17.6
	75-105	4.021	0.229	17.5
Profile III	0-15	2.472	0.142	17.4
	15-45	2.046	0.131	15.6
	45-75	1.208	0.095	12.8
	75-105	0.584	0.042	13.9
Mean of all profiles				
	0-15	2.583	0.173	14.6
	15-45	2.301	0.123	16.3
	45-75	2.071	0.129	16.1
	75-105	1.824	0.112	14.9
Mean of all Depths				
Profile I		0.977	0.081	12.3
Profile II		4.030	0.223	18.4
Profile III		1.677	0.102	14.9

TABLE XXI

Carbon, Nitrogen and C/N ratio of the soils collected from elevation 900 metres and rainfall 425 cm.

Profile and Depth (Cm.)		Carbon %	Nitrogen %	C/N Ratio
Profile I	0-15	2.116	0.175	12.1
	15-45	1.239	0.166	7.6
	45-75	1.095	0.146	7.5
	75-105	1.130	0.132	8.2
Profile II	0-15	3.362	0.204	16.4
	15-45	1.855	0.124	14.9
	45-75	1.853	0.121	15.3
	75-105	1.801	0.200	9.0
Profile III	0-15	1.773	0.121	14.6
	15-45	0.750	0.062	12.1
	45-75	0.640	0.059	10.8
	75-105	0.586	0.056	10.4
Mean of all profiles				
	0-15	2.417	0.166	14.36
	15-45	1.281	0.117	11.6
	45-75	1.196	0.109	11.2
	75-105	1.172	0.129	9.3
Mean of All Depths				
Profile I		1.395	0.154	8.9
Profile II		2.218	0.162	13.9
Profile III		0.937	0.074	11.9

TABLE XXIII

Carbon, Nitrogen and C/N ratio of the soils collected from elevation 1200 metres and Rainfall 625 cm.

Profiles and Depth (Cm.)		Carbon %	Nitrogen %	C/N Ratio
Profile I	0-15	0.431	0.086	5.0
	15-45	0.171	0.044	4.0
	45-75	0.137	0.028	4.9
	75-105	0.137	0.030	4.5
Profile II	0-15	1.514	0.131	11.5
	15-45	0.596	0.039	15.3
	45-75	0.564	0.032	14.5
	75-105	0.512	0.070	7.3
Profile III	0-15	1.023	0.146	7.0
	15-45	0.259	0.032	8.1
	45-75	0.278	0.035	7.9
	75-105	0.278	0.038	7.3
<u>Mean of all profiles</u>				
	0-15	0.989	0.121	7.8
	15-45	0.342	0.038	9.1
	45-75	0.326	0.032	9.1
	75-105	0.309	0.046	6.3
<u>Mean of all Depths</u>				
Profile I		0.219	0.047	4.6
Profile II		0.796	0.068	12.1
Profile III		0.459	0.063	7.6

TABLE XXIII

Carbon, Nitrogen and C/N ratio of the soils collected from elevation 1000 metres and rainfall 535 cm.

Profile and Depth (Cm.)		Carbon %	Nitrogen %	C/N Ratio
Profile I	0-15	2.937	0.709	4.1
	15-45	2.292	0.327	7.0
	45-75	2.350	0.449	5.2
	75-105	2.278	0.205	11.1
Profile II	0-15	4.025	0.257	15.6
	15-45	2.604	0.174	14.9
	45-75	2.221	0.089	25.0
	75-105	1.184	0.029	13.7
Profile III	0-15	2.137	0.121	17.6
	15-45	1.363	0.112	12.1
	45-75	1.128	0.102	10.9
	75-105	0.119	0.020	5.7
__Mean of all profiles__	0-15	3.029	0.362	12.4
	15-45	2.126	0.204	11.3
	45-75	1.898	0.213	13.7
	75-105	1.193	0.104	10.1
__Mean of all depths__				
Profile I		2.461	0.422	6.8
Profile II		2.531	0.162	17.3
Profile III		1.184	0.088	11.6

TABLE XXIV

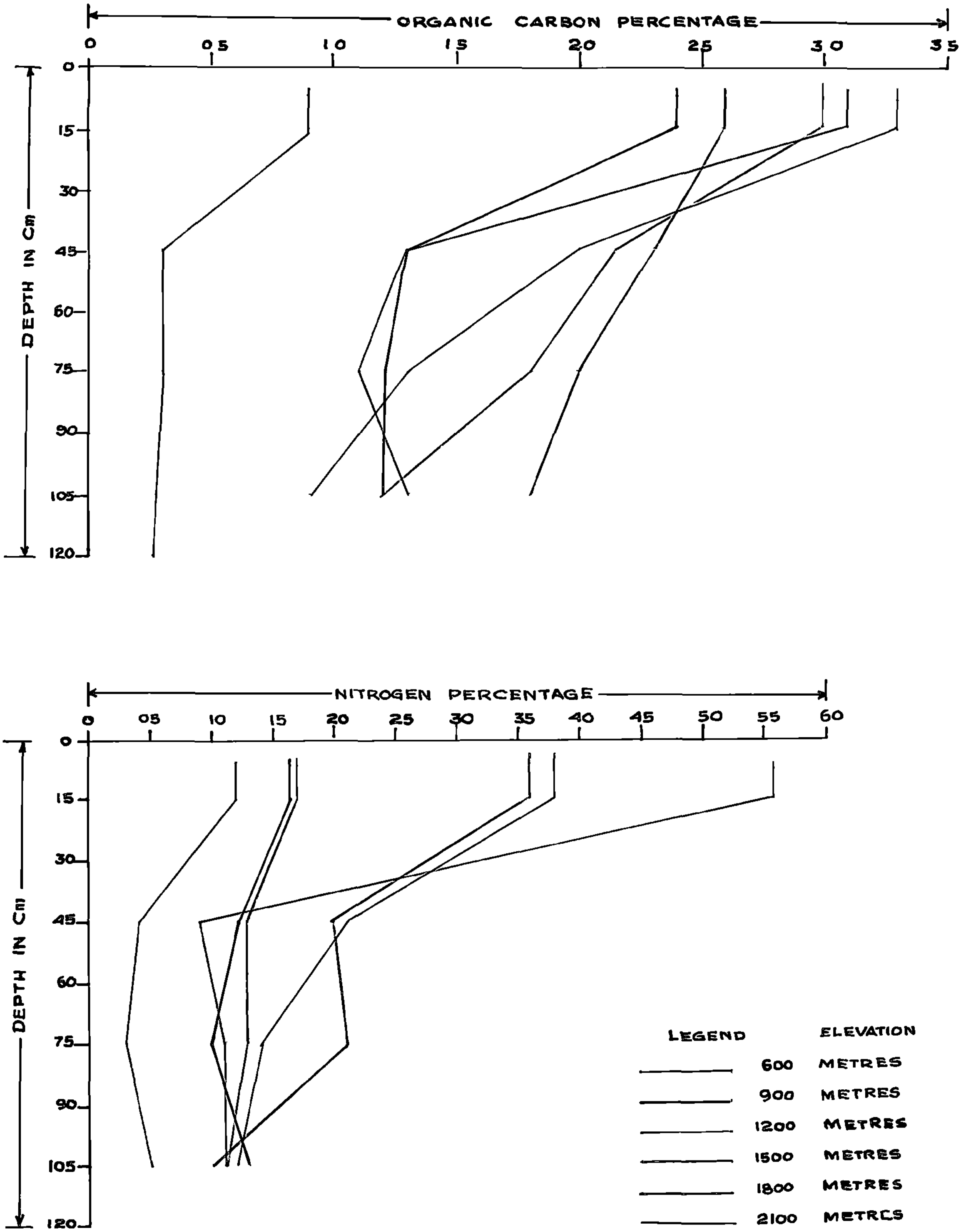
Carbon, Nitrogen and C/N ratio of the soils collected from elevation 1800 metres and rainfall 540 cm.

Profile and Depth (Cm.)		Carbon %	Nitrogen %	C/N Ratio
Profile I	0-15	2.027	0.705	4.2
	15-45	2.105	0.164	12.8
	45-75	1.427	0.084	17.0
	75-105	1.051	0.092	11.4
Profile II	0-15	4.682	0.851	5.5
	15-45	1.955	0.106	18.7
	45-75	1.802	0.200	9.0
	75-105	1.684	0.210	8.0
Profile III	0-15	1.706	0.121	14.1
	15-45	0.132	0.028	4.7
	45-75	0.179	0.032	6.2
	75-105	0.199	0.035	5.7
Mean of all profiles				
	0-15	3.105	0.559	7.9
	15-45	1.397	0.099	12.1
	45-75	1.142	0.105	7.4
	75-105	1.311	0.112	8.3
Mean of all Depths				
Profile I		1.877	0.261	11.3
Profile II		2.531	0.341	10.3
Profile III		0.559	0.054	7.7

TABLE XXV

Carbon, Nitrogen and C/N ratio of the soils collected from elevation 2100 metres and rainfall 550 cm.

Profile and Depth (Cm.)		Carbon %	Nitrogen %	C/N Ratio
Profile	0-15	2.855	0.614	4.6
	15-45	2.754	0.346	7.9
	45-75	1.116	0.167	6.7
	75-105	0.521	0.079	6.6
Profile II	0-15	5.462	0.380	14.4
	15-45	3.021	0.193	15.6
	45-75	2.631	0.191	13.7
	75-105	1.851	0.185	10.0
Profile III	0-15	2.046	0.141	14.5
	15-45	0.450	0.091	4.9
	45-75	0.245	0.051	4.8
	75-105	0.469	0.102	4.6
Mean of all profiles				
	0-15	3.454	0.378	11.2
	15-45	2.076	0.210	9.4
	45-75	1.331	0.136	8.4
	75-105	0.947	0.122	7.1
Mean of all Depths				
Profile I		1.809	0.301	6.4
Profile II		3.241	0.237	13.4
Profile III		0.802	0.096	7.2



VARIATION OF ORGANIC CARBON AND NITROGEN AS A FUNCTION OF DEPTH

FIG 2

In the soils there was significant positive correlation between elevation and organic carbon between elevations of 600 and 900 metres (r = +0.608), 900 and 1200 metres (r = +0.839), 1200 and 1500 metres (r = +0.581), 1500 and 1800 metres (r = +0.856) and 1800 and 2100 metres (r = +0.917).

(iii) Nitrogen

The analytical results pertaining to the nitrogen content of the soils are given Tables to XX to XXV and graphically represented in Fig.2.

The nitrogen content showed remarkable variation with elevation and rainfall and ranged from 0.028% in the soils at 1200 metres to 0.709% at 1500 metres. This element decreased steadily with depth in most profiles.

The elevation - nitrogen relationship was positive in all the profiles at all elevations. The relationship between rainfall and this element was significantly positive in the surface layers, but negative in the deeper layers.

The organic carbon and nitrogen had positive correlation in the soils at all elevations (r = +0.385 at 600 metres, r = +0.563 at 900 metres, r = +0.826 at 1200 metres r = +0.926 at 1800 metres, and r = +0.339 at 2100 metres).

(iv) Carbon - Nitrogen ratio

As seen in the Tables XX to XXV the C/N ratio varied from 4.0 in the soils at 1200 metres to as high a value as 25.0 at 1800 metres. The surface layer had the widest ratio when compared to the lower layers at all elevations.

(v) Acid insolubles

As shown in the Tables XXVI to XXXI the highest value for acid insolubles, viz., 69.8%, was obtained in the soils at 1200 metres and the lowest value (44.4%) was found at the elevation of 1800 metres.

(vi) Sesqui-oxides

The analytical data on the sesqui-oxides are given in Tables XXVI to XXXI. The sesqui-oxide content varied from 17.7% in the soils at 1200 metres to 42.3% in the soils at 600 metres. Vertical distribution of sesqui-oxides showed a steady increase down the profile in the soils at elevations of 600 metres, 900 metres, 1200 metres and 1500 metres but decreased with depth in profiles at elevations of 1800 metres and 2100 metres.

TABLE XXVI

Acid insoluble and Acid soluble Silica and Sesquioxides in soils from elevation - 600 metres and rainfall 325 cm.

Profile and Depth (Cm.)		Acid insolubles %	Acid soluble silica %	Sesqui-oxides %
Profile I	0-15	56.650	0.350	29.250
	15-45	51.260	0.410	32.625
	45-75	52.450	0.495	35.375
	75-105	46.600	0.160	39.150
Profile II	0-15	52.226	0.260	33.224
	15-45	47.112	0.313	36.112
	45-75	47.446	0.305	39.665
	75-105	42.112.	0.302	43.226
Profile III	0-15	53.115	0.215	32.584
	15-45	48-226	0.285	35.265
	45-75	49.102	0.346	38.275
	75-105	43.556	0.229	42.292
Mean of all profiles				
	0-15	53.997	0.275	31.689
	15-45	48.866	0.336	34.667
	45-75	49.666	0.382	37.771
	75-105	44.089	0.230	41.556
Mean of all Depths				
Profile I		51.740	0.354	34.100
Profile II		47.224	0.295	38.057
Profile III		48.499	0.269	37.106

TABLE XXVII

Acid insoluble and Acid soluble Silica and Sesqui-oxides in soils from elevation 900 metres and rainfall 425 cm.

Profile and Depth (Cm.)		Acid insolubles %	Acid soluble silica %	Sesqui-oxide %
Profile I	0-15	51.130	0.460	27.150
	15-45	50.560	0.575	31.500
	45-75	52.800	0.520	33.550
	75-105	51.225	0.550	35.775
Profile II	0-15	48.120	0.275	30.112
	15-45	47.336	0.418	34.448
	45-75	49.230	0.423	37.665
	75-105	48.446	0.445	38.226
Profile III	0-15	47.554	0.350	31.225
	15-45	46.226	0.495	34.115
	45-75	48.941	0.506	37.526
	75-105	47.212	0.521	38.229
<u>Mean of all profiles</u>	0-15	48.934	0.363	29.495
	15-45	48.041	0.496	33.354
	45-75	50.327	0.483	36.247
	75-105	48.961	0.505	37.410
<u>Mean of all depths</u>				
Profile I		51.429	0.526	31.993
Profile II		48.283	0.390	35.113
Profile III		47.483	0.469	35.274

TABLE XXVIII

Acid insolubles and Acid soluble Silica and Sesqui-oxide in soils collected from elevation - 1200 metres and rainfall 625 cm.

Profile and depth (Cm.)		Acid insolubles %	Acid soluble silica %	Sesqui-oxide %
Profile I	0-15	69.540	0.506	17.700
	15-45	63.150	0.430	18.770
	45-75	65.625	0.33[illegible]	19.200
	75-105	60.990	0.340	23.400
Profile II	0-15	64.536	0.150	22.766
	15-45	58.442	0.190	23.652
	45-75	60.486	0.223	24.226
	75-105	55.112	0.256	28.56[illegible]
Profile III	0-15	65.228	0.465	21.662
	15-45	59.929	0.421	22.782
	45-75	64.402	0.286	23.880
	75-105	54.665	0.[illegible]24	27.662
Mean of all profiles	0-15	66.442	0.373	20.706
	15-45	60.107	0.347	21.8[illegible]4
	45-75	63.524	0.281	22.436
	75-105	56.92[illegible]	0.273	26.642
Mean of all Months				
Profile I		64.826	0.402	19.767
Profile II		59.649	0.204	24.874
Profile III		61.071	0.349	23.996

TABLE XXIX

Acid insoluble and Acid soluble Silica and Sesqui-oxides in the soils collected from elevation 1600 metres and rainfall 535 cm.

Profile and Depth (Cm.)		Acid Insolubles	Acid Solubles silica %	Sesqui-oxide %
Profile I	0-15	45.120	0.705	23.700
	15-45	44.350	0.465	28.600
	45-75	49.220	0.600	29.250
	75-105	49.780	0.530	30.800
Profile II	0-15	49.036	0.200	21.221
	15-45	48.902	0.095	26.906
	45-75	53.880	0.121	27.440
	75-105	53.936	0.140	28.226
Profile III	0-15	41.552	0.496	27.665
	15-45	39.882	0.202	32.992
	45-75	40.112	0.116	32.856
	75-105	42.226	0.132	33.862
<u>Mean of all profiles</u>	0-15	45.299	0.460	24.195
	15-45	44.408	0.284	29.529
	45-75	47.737	0.275	29.782
	75-105	48.667	0.267	30.962
<u>Mean of all months</u>				
Profile I		47.120	0.575	28.087
Profile II		51.523	0.139	25.971
Profile III		40.943	0.258	31.793

TABLE XXX

Acid insoluble and Acid solublesilica and Sesqui-oxides in soils collected from elevation - 1800 metres and rainfall : 540 cm.

Profile and Depth (Cm.)		Acid Insolubles %	Acid Soluble silica %	Sesqui-oxides %
Profile I	0-15	44.475	0.225	38.750
	15-45	51.180	0.110	36.562
	45-75	51.785	0.125	34.625
	75-105	50.720	0.275	33.660
Profile II	0-15	41.225	0.160	40.292
	15-45	49.080	0.088	38.092
	45-75	49.286	0.198	36.116
	75-105	48.992	0.208	35.552
Profile III	0-15	41.229	0.262	41.212
	15-45	48.990	0.145	39.112
	45-75	48.292	0.126	37.225
	75-105	47.926	0.172	36.112
Mean of all profiles	0-15	42.309	0.216	40.084
	15-45	49.750	0.114	38.222
	45-75	49.788	0.149	35.988
	75-105	49.212	0.218	35.104
Mean of Depth				
Profile I		49.540	0.184	35.897
Profile II		47.146	0.163	37.738
Profile III		46.609	0.176	38.415

TABLE XXXI

Acid insoluble and Acid soluble silica and Sesqui-oxides in Soils collected from elevation: 2100 metres and rainfall 550 cm.

Profile and Depth (Cm.)		Acid Insolubles	Acid Soluble silica %	Sesqui-oxides %
Profile I	0-15	60.560	0.233	32.250
	15-45	57.610	0.450	25.250
	45-75	58.125	0.350	24.750
	75-105	58.520	0.300	24.500
Profile II	0-15	47.225	0.133	35.292
	15-45	54.115	0.208	28.662
	45-75	55.292	0.163	27.465
	75-105	55.612	0.150	26.562
Profile III	0-15	48.992	0.272	34.772
	15-45	55.225	0.205	28.115
	45-75	56.282	0.262	27.665
	75-105	59.116	0.245	25.212
Mean of all profiles	0-15	48.926	0.213	36.438
	15-45	55.616	0.288	27.342
	45-75	56.566	0.258	26.626
	75-105	57.749	0.232	25.424
Mean of all depths				
Profile I		56.179	0.333	26.687
Profile II		53.061	0.188	29.495
Profile III		54.903	0.246	28.941

Elevation and sesqui-oxides were related significantly positive between 600 and 900 metres ($r = +0.98$), 900 and 1200 metres ($r = +0.852$) 1200 and 1500 metres ($r = +0.766$) and 1500 and 1800 metres ($r = 0.442$) but significantly negative at 1800 and 2100 metres ($r = -0.652$).

(vii) Phosphorus

The phosphorus status of the soils ranged from 0.091% at 600 metres to 0.293% at 2100 metres. The vertical distribution of phosphorus down the profile did not show any regular variation. The phosphorus content in the surface layers increased progressively in the soils from 600 to 900 metres and then decreased in the soils from 1200 to 2100 metres. The relationship between rainfall and phosphorus was positive at all depths at all elevations. This element showed no correlation with elevation at lower altitudes, but at higher altitudes, viz., 1500 and 1800 metres, it showed a positive correlation ($r = +0.571$).

(viii) Potassium

The percentage of potassium as given in Tables XXXII to XXXVII, ranged from 0.061% in the soils at 600 metres to 0.51% in the soils at 1500 metres. There was a general tendency for the content of this element to increase with increase in

TABLE XXXII

P_2O_5, K_2O, CaO MgO in the soils collected from elevation 600 metres and rainfall 325 cm.

Profile and Depth (Cm.)		P_2O_5 %	K_2O %	CaO%	MgO %
Profile I	0-15	0.121	0.077	0.033	0.112
	15-45	0.104	0.090	0.017	0.108
	45-75	0.113	0.061	0.008	0.086
	75-105	0.091	0.188	0.011	0.055
Profile II	0-15	0.116	0.072	0.096	0.259
	15-45	0.102	0.086	0.075	0.223
	45-75	0.108	0.060	0.046	0.112
	75-105	0.090	0.182	0.035	0.076
Profile III	0-15	0.125	0.085	0.062	0.185
	15-45	0.108	0.092	0.042	0.162
	45-75	0.115	0.064	0.035	0.108
	75-105	0.093	0.052	0.028	0.065
Mean of all Profiles					
	0-15	0.121	0.078	0.064	0.185
	15-45	0.106	0.089	0.045	0.164
	45-75	0.112	0.062	0.029	0.102
	75-105	0.091	0.141	0.025	0.065
Mean of depths					
Profile I		0.107	0.104	0.017	0.090
Profile II		0.104	0.099	0.041	0.223
Profile III		0.1105	0.074	0.042	0.130

TABLE XXXIII

P_2O_5, K_2O, CaO, MgO in the soils collected from elevation 900 metres and rainfall 425 Cm.

Profiles and Depth (Cm.)		P_2O_5%	K_2O %	CaO%	MgO %
Profile I	0-15	0.140	0.256	0.013	0.052
	15-45	0.150	0.256	0.011	0.092
	45-75	0.159	0.209	0.008	0.090
	75-105	0.156	0.208	0.008	0.089
Profile II	0-15	0.120	0.254	0.053	0.069
	15-45	0.123	0.248	0.027	0.112
	45-75	0.125	0.201	0.013	0.112
	75-105	0.126	0.202	0.007	0.112
Profile III	0-15	0.145	0.242	0.048	0.051
	15-45	0.158	0.241	0.021	0.092
	45-75	0.162	0.222	0.012	0.091
	75-105	0.161	0.212	0.007	0.082
<u>Mean of all profiles</u>					
	0-15	0.135	0.251	0.038	0.057
	15-45	0.144	0.248	0.019	0.099
	45-75	0.146	0.211	0.011	0.098
	75-105	0.111	0.207	0.007	0.094
<u>Mean of depths</u>					
Profile I		0.151	0.232	0.010	0.081
Profile II		0.123	0.266	0.025	0.101
Profile III		0.156	0.229	0.022	0.079

TABLE XXXIV

P_2O_5, K_2O, CaO, MgO in the soils collected from elevation 1200 metres and rainfall 625 cm.

Profile and Depth (Cm.)		P_2O_5 %	K_2O %	CaO %	MgO %
Profile I	0-15	0.174	0.213	0.030	0.202
	15-45	0.178	0.220	0.022	0.102
	45-75	0.121	0.150	0.022	0.098
	75-105	0.167	0.240	0.022	0.098
Profile II	0-15	0.152	0.202	0.060	0.266
	15-45	0.156	0.272	0.035	0.179
	45-75	0.115	0.142	0.051	0.262
	75-105	0.142	0.232	0.050	0.284
Profile III	0-15	0.179	0.216	0.032	0.285
	15-45	0.182	0.225	0.048	0.162
	45-75	0.125	0.185	0.042	0.115
	75-105	0.171	0.242	0.041	0.099
Mean of all profiles					
	0-15	0.168	0.210	0.037	0.251
	15-45	0.172	0.259	0.035	0.147
	45-75	0.120	0.159	0.038	0.158
	75-105	0.160	0.238	0.038	0.160
Mean of Depths					
Profile I		0.160	0.221	0.024	0.125
Profile II		0.141	0.212	0.046	0.248
Profile III		0.164	0.217	0.041	0.165

TABLE XXXV

P_2O_5, K_2O, CaO, MgO in the soils collected from elevation 1500 metres and rainfall 535 Cm.

Profile and Depth (Cm.)		P_2O_5 %	K_2O%	CaO %	MgO %
Profile I	0-15	0.154	0.510	0.018	0.062
	15-45	0.132	0.456	0.015	0.112
	45-75	0.140	0.463	0.013	0.092
	75-105	0.149	0.366	0.013	0.071
Profile II	0-15	0.135	0.412	0.025	0.077
	14-45	0.122	0.365	0.014	0.146
	45-75	0.131	0.372	0.030	0.085
	75-105	0.142	0.302	0.039	0.075
Profile III	0-15	0.142	0.380	0.022	0.066
	15-45	0.135	0.321	0.018	0.126
	45-75	0.126	0.312	0.014	0.116
	75-105	0.105	0.306	0.012	0.082
Mean of all profiles					
	0-15	0.144	0.434	0.022	0.051
	15-45	0.129	0.381	0.012	0.128
	45-75	0.132	0.382	0.014	0.098
	75-105	0.132	0.324	0.021	0.076
Mean of depths					
Profile I		0.144	0.449	0.014	0.084
Profile II		0.132	0.363	0.027	0.096
Profile III		0.127	0.329	0.016	0.097

TABLE XXXVI

P_2O_5, K_2O, CaO, MgO in the soils collected from elevation 1800 metres and rainfall 540 cm.

Profile and Depth (Cm.)		P_2O_5 %	K_2O %	CaO %	MgO %
Profile I	0-15	0.167	0.441	0.060	0.062
	15-45	0.121	0.371	0.024	0.075
	45-75	0.179	0.399	0.024	0.068
	75-105	0.175	0.435	0.016	0.065
Profile II	0-15	0.155	0.402	0.043	0.063
	15-45	0.108	0.331	0.040	0.080
	45-75	0.167	0.352	0.032	0.078
	75-105	0.162	0.392	0.029	0.077
Profile III	0-15	0.162	0.415	0.048	0.075
	15-45	0.142	0.386	0.034	0.092
	45-75	0.154	0.401	0.032	0.066
	75-105	0.135	0.376	0.032	0.065
Mean of all profiles					
	0-15	0.161	0.419	0.048	0.067
	15-45	0.123	0.362	0.032	0.082
	45-75	0.167	0.384	0.029	0.070
	75-105	0.157	0.401	0.026	0.069
Mean of Depths					
Profile I		0.160	0.411	0.031	0.067
Profile II		0.148	0.360	0.036	0.074
Profile III		0.148	0.394	0.036	0.074

TABLE XXXVII

P_2O_5, K_2O, CaO, MgO in the soils collected from elevation 2100 metres and rainfall 550 cm.

Profile and Depth (Cm.)			P_2O_5 %	K_2O %	CaO %	MgO %
Profile	I	0-15	0.121	0.404	0.024	0.108
		15-45	0.293	0.359	0.016	0.143
		45-75	0.244	0.252	0.016	0.098
		75-105	0.199	0.305	0.016	0.086
Profile	II	0-15	0.112	0.359	0.046	0.119
		15-45	0.255	0.309	0.025	0.161
		45-75	0.212	0.202	0.038	0.106
		75-105	0.163	0.262	0.032	0.094
Profile	III	0-15	0.225	0.365	0.018	0.108
		15-45	0.205	0.345	0.012	0.162
		45-75	0.212	0.326	0.010	0.104
		75-105	0.202	0.340	0.008	0.098
Mean of all profiles						
		0-15	0.152	0.376	0.029	0.112
		15-45	0.251	0.338	0.018	0.152
		45-75	0.223	0.260	0.021	0.069
		75-105	0.184	0.302	0.019	0.092
Mean of Depths						
Profile	I		0.214	0.330	0.018	0.109
Profile	II		0.183	0.283	0.036	0.117
Profile	III		0.211	0.344	0.012	0.118

elevation with the exception of 1200 and 1800 metres.

The correlation between rainfall and potassium content was positive at all depths of soil at all elevations ('r' ranged from +0.671 to +0.726).

(ix) Calcium

The calcium content of soils varied from 0.008% in the soils at 900 metres to 0.063% at 1800 metres. The calcium content decreased down the profiles at all the elevations. The relationship between calcium content and rainfall was positive at all horizons at all elevations ('r' ranges from +0.207 to +0.964).

(x) Magnesium

The magnesium content of soils is presented in Tables XXXII to XXXVII. The variation in magnesium content was from 0.051% in the soils at 900 metres elevation to 0.202% in the soils at 1200 metres. It tended to decrease with depth in most of the profiles.

The correlation between elevation and magnesium was negative in the soils at all elevations except at the elevation of 2100 metres where it was significantly positive (r = +0.84).

The relationship between rainfall and magnesium was negative at 0-15 cm and 15-45 cm, but was significantly positive at deeper layers. ('r' ranged from 0.540 to 0.607).

III Analysis of clay fraction

The characteristics of the clay fraction of the surface samples are presented in Table XXXVIII and represented graphically in Fig.3.

a) Silica

The highest silica content was seen in the samples from an elevation of 2100 metres (48.5%) and the lowest value (25.1%) was obtained at an elevation of 900 metres.

b) Alumina (Al_2O_3)

The highest content of alumina was seen in the soils at the elevation of 2100 metres (34.5%) and the lowest value of 22.9% was noted at the elevation of 1200 metres.

c) Iron oxide

The highest value of Fe_2O_3 (22.9%) was found in the soils at an elevation 2100 metres and the lowest value (11.1%) was obtained in the soils at an elevation of 1200 metres.

IV. Molecular Ratios

The $SiO_2 : Al_2O_3$ ratio varied from 1.72 to 2.39. The lowest value was obtained in the soils at 1200 metres elevation and the highest value was found at 2100 metres' elevation.

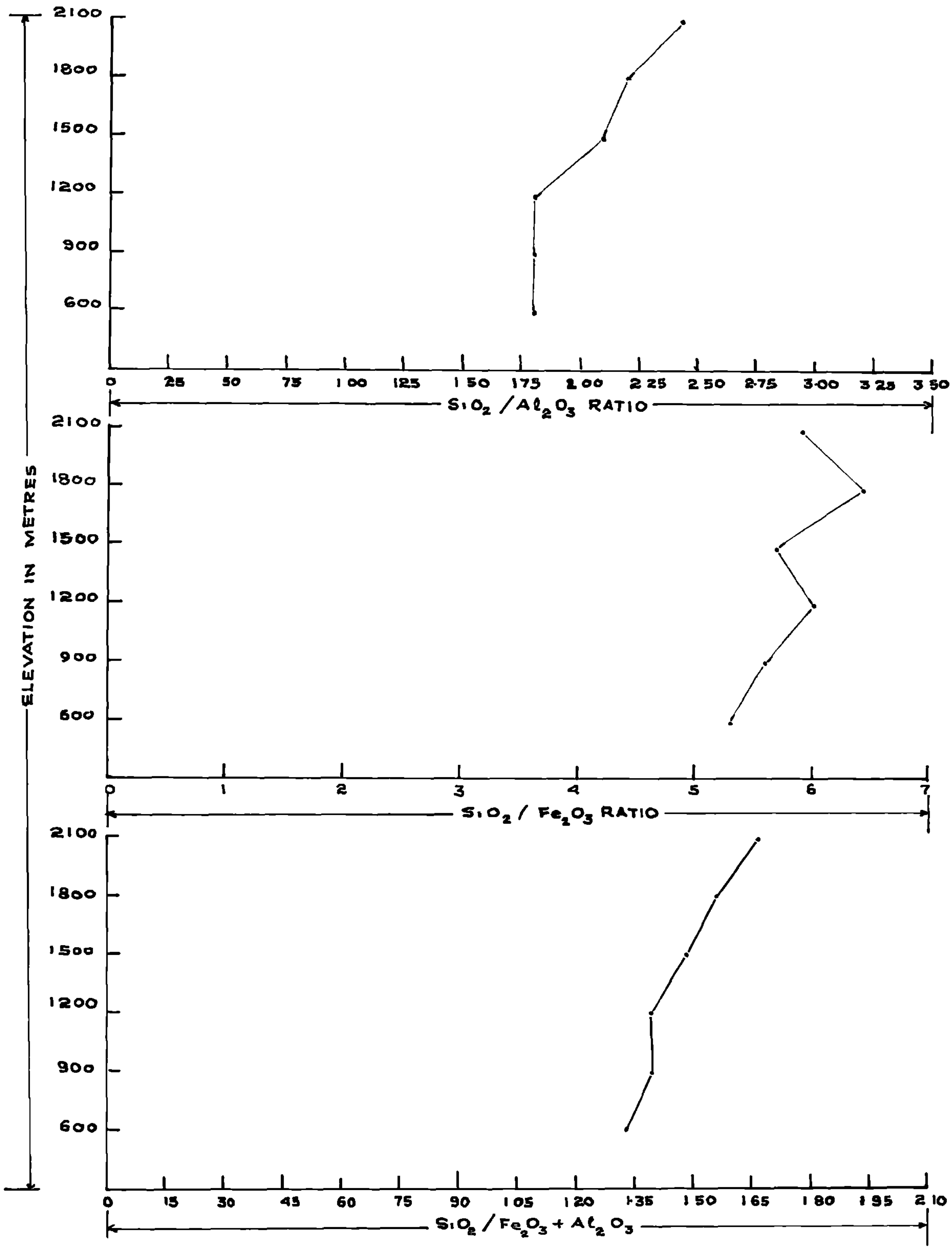
$SiO_2 : Fe_2O_3$ ratio varied from 5.11 to 6.73. The soils at 600 metres' elevation had the lowest value and those at 1800 metres' elevation had the highest value.

$SiO_2 : R_2O_3$ ratio varied steadily from 1.3 at 600 metres' elevation to 1.7 at 2100 metres' elevation.

TABLE XXXVIII

Chemical character of the clay fraction of surface soils

Elevation	Profile	Percentage on over dry basis: SiO_2	Al_2O_3	Fe_2O_3	Molecular ratios: $\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Fe_2O_3 + Al_2O_3}$
600 metres	I	29.71	28.25	15.22	1.79	5.21	1.33
	II	30.41	29.15	15.93	1.77	5.11	1.31
	III	28.61	27.51	13.12	1.76	5.79	1.35
900 metres	I	27.22	25.82	13.42	1.77	5.42	1.34
	II	25.63	24.39	12.95	1.84	5.43	1.37
	III	29.19	25.34	13.34	1.96	5.85	1.46
1200 metres	I	25.30	23.23	11.12	1.84	6.10	1.41
	II	25.13	22.92	11.69	1.85	6.81	1.41
	III	27.26	26.83	12.23	1.72	5.97	1.34
1500 metres	I	33.39	27.15	14.94	2.09	5.97	1.55
	II	33.35	28.25	15.42	2.00	5.78	1.48
	III	30.91	27.46	15.12	1.91	5.47	1.41
1800 metres	I	37.84	29.21	16.13	2.21	6.24	1.63
	II	33.56	26.92	14.24	2.11	6.28	1.57
	III	35.94	28.82	14.29	2.11	6.73	1.61
2100 metres	I	48.50	34.45	22.94	2.39	5.65	1.68
	II	44.31	31.91	19.83	2.35	5.95	1.68
	III	42.06	30.13	18.74	2.37	6.04	1.70



MOLECULAR RATIOS OF THE CLAY FRACTION AS A FUNCTION OF ELEVATION

FIG 3

TABLE XXXIX

Physical and Chemical properties of the soils

Property (Average of all profiles and depths)	600 metres	900 metres	1200 metres	1500 metres	1800 metres	2100 metres
I. Mechanical Composition						
(a) Coarse sand %	33.6	25.9	38.1	21.4	22.9	26.6
(b) Fine sand %	11.0	11.8	21.3	12.7	7.6	10.9
(c) Silt %	7.3	8.6	17.4	17.1	17.4	11.8
(d) Clay %	44.1	51.1	22.4	45.2	49.3	47.9
(e) Organic matter %	4.0	2.6	0.8	3.6	2.8	3.3
II. Single value constants						
(a) Apparent density	1.4	1.3	1.3	1.2	1.2	1.2
(b) Absolute specific gravity	2.6	2.6	2.8	2.2	2.2	2.1
(c) Maximum water holding capacity %	35.2	40.1	34.6	40.5	34.3	32.6
(d) Percentage of pore space %	53.0	42.3	42.7	44.2	36.3	34.7
III pH	5.3	5.1	4.6	5.2	6.4	5.7
IV Moisture %	5.1	7.8	4.7	9.9	9.4	9.4
V Loss on ignition %	13.6	10.9	7.6	24.4	20.2	21.0
VI Carbon . . . %	2.19	1.52	0.49	2.06	1.66	1.95
VII Nitrogen . . . %	0.14	0.13	0.06	0.22	0.22	0.21
VIII C/N Ratio . .	15.6	11.7	8.1	9.3	7.5	9.3
IX P_2O_5 %	0.107	0.143	0.155	0.134	0.152	0.202
X K_2O %	0.092	0.242	0.216	0.350	0.391	0.319
XI CaO %	0.033	0.019	0.037	0.019	0.034	0.021
XII MgO %	0.147	0.087	0.176	0.092	0.071	0.114
XIII SiO_2/Al_2O_3	1.77	1.86	1.80	2.00	2.14	2.37
XIV SiO_2/Fe_2O_3	5.37	5.56	5.96	5.74	6.41	6.88
XV $SiO_2/Fe_2O_3 + Al_2O_3$	1.33	1.32	[illegible]	1.48	1.60	1.68

DISCUSSION

DISCUSSION

The present investigation comprises a study of the effect of elevation and rainfall on the chemical and physical properties of the soils of the High Ranges in Kerala State. The range of elevation covered in the study is from 600 metres to 2100 metres. The annual rainfall of the region varies from 328 cm. to 626 cm., the highest rainfall being at the elevation of 1200 metres.

The soils exhibit a wide range of colours such as dark grey, dark brown, dark reddish brown, yellowish red and dark reddish brown. The dark colour of the surface horizon changes to red in the sub soil. The brown colour of the surface horizon may be due to the presence of iron oxides with accumulations of humus. The colour is lighter at the elevation of 1200 metres and the intensity ofthe colour increases with increase or decrease in elevation. The higher rainfall at 1200 metres might be responsible for the hydration of iron oxides and the consequent lighter colour. Craig and Halais (1934) also observed similar conditions in Mauritius soils and Ritcher (1931) noted that such gradations of colour are functions of rainfall.

The general features of the soils reveal that they are of the lateritic type. The silica - alumina molecular ratio of the clay of the surface samples varies from 1.76 to 1.86 as the elevation varies from 600-900 metres and from

1.91 to 2.39 when the elvation changes from 900-2100 metres. The lower regions may therefore be considered as consisting of laterites and higher regions of non-laterites according to the definition of Martin and Doyne (1927). According to Raychaudhuri and Sulaiman (1940), the silica - alumina ratio of Indian laterites may be even higher than 2. In that case the soils in general has to be considered as laterites or as lateritic.

The mechanical analysis data and textural classification of the soils indicate that the soils are either clay or clay loams. The first two layers (0-30 cm. and 30-45 cm.) contain the highest amounts of clay and there is a gradual decrease in the clay content down the profile. Similar observations were also made by Ricardo (1958). At 1200 metres the clay content shows a sudden decrease in the intermediate layers and the decrease continues to the lower depths. The clay content of the surface sample is more in the profiles from elevations other than 1200 metres. Considering the other properties of the soil also there is every reason to infer that this elevation is a critical one with respect of the physico-chemical properties of soils. Costin et al (1952) found in the Alpine soils such a critical elevation above and below which there was appreciable variation in the content of clay. The data for clay analysis in this study are similar to those obtained by Rajagopal and Idnani (1963) for Nilgiri soils. There is an increase in the content of clay from 1800 metres, where the rainfall is a maximum to 600 metres where the rainfall is a minimum. This may be due to difference in the vertical translocation of clay brought about by the differences in rainfall. Similar observations were also made by Govindarajan and Datta Biswas (1968) in the soils of the Machkund basin and by Mahalingam (1962) in Nilgiri soils.

The water holding capacity is found to be highest in the soils developed at 1800 metres and having a clay content of 60.2%. The soils with the lowest clay content has also the lowest water holding capacity. It can therefore be assumed that the clay content of the soil is related to the water holding capacitywhich agrees with the findings of Mahalingam (1962) for Nilgiri soils. Apart from this apparent relation, there is no positive correlation between the clay content and moisture holding capacity which agrees with the view of Sen and Deb (1941) that moisture contents of heavy soils may not have any relation to the clay content.

In the soils studied the pore-space varies from 23.8% to 53.2% which agrees with the findings of Burger (1923) who noted that the pore space of forest soils varied from 28 to 69%.

A positive correlation was also noted between the clay content and pore space. This may be due to the large proportion of capillary pores present in the finer fraction.

The loss on ignition which is an approximate measure of the organic matter content is positively correlated to the clay content. The cooler climate in these regions might have favoured a higher production of Organic matter, which is reflected in the relatively higher values for loss on ignition. Mahalingam (1962) also found such relations in Nilgiri soils.

The highest acidity (pH 4.4) is noticed at an elevation of 1800 metres where the rainfall is a maximum. The acidity can be attributed to the long and continued leaching of soils. Therefore it should be inferred that rainfall has a more pronounced effect than elevation on the development of acidity. Similar observations have also been made by Dhanaraj (1966) in Mysore soils and Nambiar (1963) in Madras soils. The cause of high acidity of the soils may also be attributed to the higher addition of organic matter and production of organic acids by its decomposition. Hasselman (1926) also observed that forest soils developed acidity if the trees occupying the land contained a lower amount of bases.

The soils studied are characterised by relatively higher amounts of carbon and nitrogen. It has been found that elevation has a significant positive correlation to the contents of nitrogen and organic carbon. This may be due to the high moisutre content of the soils which favours a vigorous plant growth and consequently higher organic matter production at higher elevations. Furthermore, as the elevation increases the climate becomes cooler which favours accumulation rather than humification of organic matter. This observation is in agreement with the findings of Jenny and Raychaudhuri (1952), Unnikrishnan (1961), Mahalingam (1962), Nambiar (1963) and Vijaya Chandran (1963). The present investigation reveals that nitrogen content of the soils is high and has a positive correlation with rainfall and elevation which is in accordance with the findings of Alway (1916), Sievers and Holtz (1923), Dean (1937), Ray Chaudhuri and Sen (1957), Unnikrishnan(1961), Mahalingam (1962), Ray Chaudhuri and Anjaneyalu (1965). The organic carbon content of the soil profile decreases with depth at all elevations which is evidently due to the vertical translocation of organic matter from the upper to the lower horizons by leaching. Similar observations were also made by Powers (1962) in forest soils. The soils developed at 1200 metres, which has the maximum rainfall, contain only low levels of organic carbon and nitrogen. As discussed earlier this elevation is a critical one with gradation in soil properties in both directions and the low content of organic carbon and nitrogen can only be explained as due to the high leaching conditions prevailing at this elevation.

The analytical data show that the carbon-nitrogen ratios of the soil varies from 4 to 25. According to Satynarayana et al (1946) and Yadav and Pathak (1963) a similar range is observed in the uncultivated and forest soils of India. The high C/N ratio observed in some of the soils might be due to the reduced activity of micro-organisms under the acid conditions and low temperature prevailing at the higher elevations. Ray Chaudhuri and Anjaneyalu (1965) also got similar results in a study of the foot-hill soils of the Himalayas.

The present study shows that the surface soils are some times richer and some time poorer in phosphorus, than the corresponding sub soils. This is in agreement with the findings of Walker and Adam (1959) that a decrease in total phosphorus with increased degree of leaching was due more to a decrese in bulk density associated with higher levels of organic matter than to the actual loss of phosphorus. The phosphorus content of the soils varies from 0.091% to 0.293% which agrees with the findings of Britomutunayagam and Koshy (1951) for the soils of Kerala and Yadav and Pathak (1963) for the forest soils of India. At 600 to 1800 metres, there is a positive correlation between the phosphorus content and loss on ignition which is a rough measure of the organic matter content. The relation between phosphorus and nitrogen is found to be positive at 600 metres' elevation and there is no correlation between the two at higher elevations. These differences can be attributed to the difference in the quantum of organic matter naturally added to the soil and the varied nature of its decomposition products at the different elevations. In Nilgiri soils Gopalaswamy et al (1962) also found similar correlations between organic carbon and phosphorus at elevations above 1800 metres and between nitrogen and phosphorus at altitudes above 600 metres.

The data on sesqui-oxides reveal that they have been leached from the surface soil to the lower horizons in all profiles except those developed at 1800 metres and 2100 metres. The extent of leaching of the sesqui-oxides varies at the different elevations. The differences may be attributed to the differences in the amount of complexing agents produced as a result of organic matter decomposition in the leaching medium. (Bloomfield, 1956; Thomas, 1964).

The study shows that calcium content is highest in the surface soils and it decreases down the profile at all elevations. This observation agrees with the findings of Rost and Zetterberg (1932) and of Thomas (1964). The high content of calcium in the surface soil may be due to the accumulation of this element through leaf fall. Elevation has no appreciable influence on the content of calcium except at elevations above 1800 metres which may be due to the differences in the type of vegetation in the area.

The analytical data reveal that magnesium content has no relation to elevation from 600 metres to 1800 metres, but above that elevation there is positive correlation between the two. The relation between rainfall and the content of magnesium is negative which may be due to the leaching conditions consequent on a high rainfall. The leaching of magnesium by rainfall is a serious problem affecting the productivity of the soils of this region.

The observations have revealed that 1200 metres is a critical elevation from where the Physico-chemical properties of soils change in both directions. It is also seen that the nature and content of organic matter of forest soils control to a great extent the distribution transformation and translocation of other nutrient elements.

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS

A study has been undertaken of the soils of the High Ranges of Kerala to investigate the influence of elevation and rainfall on the physical and chemical properties of the soils. The elevations from which the soils were collected varied from 600 metres to 2100 metres and the rainfall from 328 cm. to 625 cm.

The chief findings are summarised below:-

(1) The soils exhibit a wide range of colours such as dark grey, dark brown, reddish brown, yellowish red and dark reddish brown. The colour of the soil is lighter at 1200 metres due to the hydration of the sesquioxides consequent on the high rainfall received at this elevation.

(2) The surface horizon generally contains the maxium amount of clay which decreases with depth down the profile. The translocation of clay is maximum in the soils collected from an elevation of 1200 metres where the highest amount of rainfall is received. The clay content of the soils is correlated to their water holding capacity.

(3) The highest acidity is noticed in the soils developed at an elevation of 1200 metres.

(4) All the soils are characterised by relatively higher amounts of carbon and nitrogen. There is significant positive correlation between elevation and the contents of these elements. The organic carbon content of the soils decrease with depth at all elevations which may be due to the effect of leaching. The carbon-nitrogen ratio varies from 4 to 25.

(5) The surface soils generally show a higher content of phosphorus than the corresponding sub soils. There is positive correlation between phosphorus content and organic matter in the soils from elevations of 600-1800 metres. The relationship between phosphorus and nitrogen is found to be positive only at 600 metres.

(6) The sesqui-oxides have been leached downward from the surface soils at all elevations except in the soils at 1800 metres and 2100 metres.

(7) The calcium content is highest in the surface soils and it decreases down the profile at all elevations.

(8) The magnesium content of the soils has no relation to elevation from 600 metres to 1800 metres, but there is a positive correlation above that elevation. The magnesiu content of the soils is inversely proportional to the rainfall.

(9) The clay fraction analysis has shown that soils are laterites or lateritic.

(10) The elevation of 1800 metres which has the highest rainfall is a critical one as far as soil characteristics are concerned because most soil properties are found to be either a maximum or minimum at this elevation.

REFERENCES

REFERENCES

Abhiswar Sen, Ukyl, A.C. Mukherjee. S.K. and Viswanath, B	1946	Comparative study on Indian Soils IV Mechanical analysis of soil properties Ind. J. Agric. Sci. 16: 246-250
Aldrich, D.C. and Buchanan, J.R.	1954	Phosphorus content of soils and the parent rock in Southern California. Soil. Sci. 77 : 369-376
Alway, F.F.	1916	The loess soils of Nebraska portion of the transition I, II Soil. Sci. 1: 197-258.
Alway, F.J. and Blish, M.J.	1916	Loess soils ofthe Nebraska portion of the transition region, humus, humus nitrogen and colour. Soil. Sci. 1: 230-258
Alway F.T. and Islam, R.M	1916	The loess soils of Nebraska portion of the transition region IV Mechanical Composition and inogranic constitutents. Soil. Sci. 1: 405-435.
Aristorenas	1937	A study of certain Physical and chemical characteristics of some Maquill ng soils Phillipp. Agric. 26: 642-65[illegible]
Birch, H.F. and Friend, M.T.	1956	The organic matter and nitrogen status of East African soils. J. Soil. Sci. 7: 156-167.

Bloomberg, H.F. and Holmes, W. 1959 The Carbon nitrogen ratio in some Hawaiian soils. Hawaii. agric. Expt. Sta. Progr. Rep. 1. 22: 7

Bloomfield, C 1955 Leaf leachates as a factor in Pedogenesis J. Sci.Fd. Agric. 6 : 641-651

Brito Mutunayagam, A.P.A and Koshy, M.M. 1951 Chemical nature and distribution of phosphorus in soils Travancore-Cochin. Bull. Cent. Res. Inst. Univ. Travancore 2: 68-76

*Burger Hans. 1923 Physikalische Eigenschatften der wald-und Freilandboden Buhler-Buchdruck.Zürich pp.221.

Costin, A.B. Halls worth, E.G. and Woof, M. 1952 Studies on pedogenesis in New South Wales III Alpine Humus soils. J. Soil Sci.3: 190.

Costing, A.B. 1955 A note on the basalt soils in Britain and Australia J. Soil Sci. 6: 268-269.

Coutts, J.R.H. 1929 Single value soil properties, a study of the significance of certain soil constants II. Studies in Natal soils. J. agric. Sci.19:325-341.

Craig, N. and Halais, P. 1934 The influence of maturity and rainfall on the properties of laterite soils in Mauritius. Emp.J. Expt. Agric. 2:349-353

Crowther, E.M.	1930	The relationship of climate and geological factors to the composition of the soil clay and distribution of soil types. _Proc. Roy. Soc. Bull. 107_: 1-30.
Dames, T.W.G.	1955	The soils of Central Java. _Contributions of the General Agricultural Research Station Bogor._
Das, S. Mukherjee, S.K. Athiswar Sen and Viswanath, B.	1946	Comparative Studies on Indian Soils III. Base exchange properties. _Indian. J. Agric. Sci. 16_ : 234-239.
Dean, L.A.	1937	The effect of rainfall on the Carbon and Nitrogen Content and C/N ratios in Hawaiian Soils. _Soil. Sci. Soc. Amer. Proc. 2_ : 455-460.
Dhanaraj, D.	1966	A study of the nutrient status of Mysore State soils as influenced by elevation and rainfall. _Dissertation Submitted to and accepted by the University of Madras._
Dhir, R.P.	1967	Pedological characteristics of some soils of North Western Himalayas. _J. Indian. Soc. Soil. Science. 13_ : 61-69.
Dockuchaev, V.V.	1889	Quoted by Jacob.S. Joffe in _A.B.C. of soils._

Durairaj, D.J.	1961	Study of the soil types of South India in relation to their colour and physical and chemical properties. Thesis submitted to the University of Madras.
Ghani, M.O. and Aleem, S.A.	1943	Studies on the distribution of different forms of phosphoru in some Indian Soils II Depth distribution. Ind. J. Agric. Sci. 13:377-381.
Gopalaswamy, A. Natarajan, R. Rengaswamy, P. and Gopalakrishnan, V.	1968	Relationship between loss on ignition, Nitrogen and Phosphor in the Alluvial and laterite soils of Madras State. J. Ind. Soc. Soil Sci. 16 : 379-382.
Govindarajan, S.V. and Datta Biswas, N.R.	1968	Characterisation of certain soils in the sub-tropical Humid Zones in the South eastern part of India-soils of Machkund Basin. J. Ind. Soc. Soil. Sci. 16:2: 179-186.
Hallsworth, R.G. Costing, A.I., Coblins, F.R. and Robertson, G.K.	1952	Studies on pedogenesis in New South Wales J. Soil Sci. 3 : 103-124.
Harradine, F. and Jenny, H.	1958	Influence of parent material and climate on texture, nitrogen and carbon contents of Virgin California Soils.1. Texture and nitrogen contents of soils. Soil. Sci. 85 : 235-243.

* Hesselman Henrick	1926	Studies over Larrskogens humustacke, dessegenskapor och beroendi an skogsvarden Middel. f. <u>Statens Skogsforsok-ansstalt.</u> <u>22</u> : 169-552.
Hockensmith, R.D. and Tucker, E.	1933	The relation of elevation to nitrogen content of grass land and forest soils in Rocky mountains of Colorado <u>Soil</u> : <u>Sci.</u> <u>36</u>: 41-46.
Hopkins C.G.	1910	<u>Soil fertility and permanent Agriculture</u> Ginn and Company Boston.
Issac, W.E. and Gerhill, B	1936	The organic matter content and Carbon nitrogen ratios of some semiarid soils of Cape province. <u>Trans. Roy. Soc. South Africa.</u> <u>23</u>: 245-254.
Jackson, M.L.	1958	<u>The Soil Chemical Analysis.</u> McGraw Hill Book Co. Inc. New York.
Jenny, H.	1928	Relation of climatic factors to the amount of nitrogen in soils. <u>J. Amer. Soc. Agron:</u> <u>20.</u> 900-912.
Jenny, H.	1930	The Nitrogen Content of the soils as related to the precipitation evoparation ratio. <u>Soil. Sci.</u> <u>29</u>: 193-207.

Jenny, H. and Leonard.	1934	Functional relationship between soil properties and rainfall Soil. Sci. 38: 363-381.
Jenny, H.	1941	Factors of soil formation Mcgraw Hill Co. New York and London.
Jenny, H.	1950	Causes of high nitrogen and organic matter content of certain tropical forest soils. Soil. Sci. 69: 1-6.
Jenny, H. and Ray Chaudhuri, S.P.	1958	Effect of climate and cultivation on the organic matter reserves of Indian soils ICAR New Delhi.
Jensen, H.L.	1929	On the influence of Carbon nitrogen ratios of organic material on the mineralisation of nitrogen. J. Agric. Sci. 19. 71-75.
Joachim, A.W.R. and Kandiah, S.	1947	Studies on Ceylon soils XVII and XVIII. The physical and physico-chemical charactorstics of the major soil types of Ceylon. Trop. agric. 103 : 71-84.
Joffe, J.S.	1949	A.B.C. Soils.
Joshy, K.V. Pharande, K.S. and Dixit, L.A.	1960	Soils of Sugar Cane areas in Kolhapur District. J. Ind. Soc. Soil. Sci. 9 157-167.

Kanwar, J.S. and Grewal, J.S. 1959 Forms of phosphorus in Punjab Soils. *Ind. Soc. Soil. Sci. 7*: 135-146.

Karim, A. and Khan, D.H. 1956 Vertical distribution of Nitrogen, phosphorus and potassium in some soils of East Pakistan. *Soil. Sci. 81*: 1-6.

Keen, B.A. and Raczkowski. 1921 The relationship between clay content and certain physical properties of soils. *J. Agric. Sci. 11*: 441-449.

Mahalingam, P.K. 1961 A study of the physical and Chemical properties of the high level Nilgiri soils *Dissertation for M.Sc. (Ag.) submitted to and accepted by the* University of Madras.

Martin, F.J. and Doyne, H.C. 1927 Laterite and lateritic soils of Sierra Leone. *J. Agric. Sci. 17*: 530-547.

Mclean, W. 1930 The carbon nitrogen ratio of Soil organic matter. *J. Agric. Sci. 20*: 348-356.

Merchand, L.D. 1924 Some physical properties of Transvaal Soils. *J. Agric. Sci. 14*: 151-169.

Mohr, E.C.J.	1913	quoted by Sonstius M.V. Agro geological studies in Tropics.1. high altitudes oriental tropics. Soil. Res.2: 30-54.
Muir, J.W.	1955	The effect of soil forming factors over an area in the South of Scotland. J. Soil. Sci. 6: 84-93.
Mukherjee, L.K. and Agarwal, R.R.	1943	Studies on Bundelkhand Soils I. The genetic types. Ind. J. Agric. Sci. 13: 587-597.
Mutkar, V.K. and Ray Chaudhuri, S.P.	1959	Carbon and Nitrogen status of arid and Semiarid regions of India. J. Ind. Soc. Soil Sci. 7: 256-262.
Paul I. Vlasoff and Lawrence. C. Wheeting.	1937	Characters of certain soil profiles of South Eastern Washington. Soil. Sci. 14: 65-81.
Piper, C.S.	1950	Soil and plant Analysis The University of Adelaide Adelaide, Australia.
Powers, W.L.	1932	Characterstics of forest soils of North Western United States. Soil. Sci. 34: 1-10.
Premanathan, S. Durairaj, D.	1966	A study of the Alluvial soils of Madras State. Madras. Agri. J. (2): 49-54

Puttaswamy Gowda, B.S. 1960 Investigations on Red Soil formation under different climatic conditions and parent material. Dissertation for the award of Postgraduate Diploma in I.A.R. I., New Delhi.

Rajagopal, C.K. Idnani, M.A. 1963 Some aspects of phosphorus fertilization in the Nilgiri soil. J. Ind. Soc. Soil. Sci. 2: 142-150.

Ramann 1911 Quoted by Das, S. in Vertical distribution of phosphate in calcareous soils. Ind. J. Agric. Sci. 16: 164-168.

Raychaudhuri, S.P. and Sulaiman, M. 1940 Studies on the Chemical constituents of Indian laterite and red soils I Determination of free sesquioxide components. Ind. J. Agri. Sci: 10 (2) 158-163.

Raychaudhuri, S.P. and Mukherjee, M.K. 1941 Studies on Indian red soils III General morphological characteristics of some profiles. Ind. J. Agri. Sci. 11: 236-240.

Raychaudhuri, S.P. and Chakraborthy, J.N. 1943 Studies on Indian red soils IV influence of rainfall and altitude above sea-level on the Chemical composition of the clay fraction of the soil types. Indi. J. Agric. Sci. 13: 252.

Raychaudhuri, S.P. and Mian, M.	1944	Studies on Indian red soils VIII. Studies on the physico-chemical and minerological properties of some Indian red and laterite soils. Indian J. Agric. Sci. 14: 117-129.
Raychaudhuri, S.P.	1967	As reported by Raheja in Soil Productivity and crop growth.
Raychaudhuri, S.P. Anjoneyalu, B.S.R. and Shuka, S.S.	1965	Studies ofsome Foothill soils of Himalayas. J. Ind. Soc. Soil Sci: 13: 116-122.
Retzer, KL.	1948	Soils developed from Basalt in Western Colerado. Soil. Sci. 66: 365-375.
Ricardo. E. John	1958	The Guataparo Red soils of Northern Venezulla. Soil. Sci. 86: 1-6.
*Ritcher, G.	1931	Physical properties of Hawaii Soils with special reference to the Colloidal fraction. Hawaii. Agric. Expt. St. Bull. 62: 1-46.
*Roberts, R.C.	1942	Soils of puerto Rico U.S.D.A. Bur. plant. Indust. Ser. 1936 No.2.

Roy. L. Donahue	1958	Soils, an introduction to soils and plant growth. Engle wood Cliffs, N.J. Prentice-Hall INC.
Rost, C.O. Jean, M and Zetterberg.	1932	Replaceable bases in the soils of Eastern minnesota and the effect of lime upon them. Soil. Sci. 33:
Russel, J.C. and Engle, E.J.	1925	Soil Horizons in the Central Prairie. Rept. Fifth Meeting Amer. Soil. Survey. Assoc. 6: 1-18.
Russel, J.C. McRuer, Wm.G.	1927	The relation of organic matter and nitrogen content to Series and types in Virgin grass land soils. Soil. Sci.: 24: 421-451.
Sadanandan Nambiar.	1963	A study of the major soil groups of Madras State. Dissertation submitted to and accepted by the University of Madras.
Smolick	1926	Quoted by Jenny, H. Soil. Sci. 29: 1930.
Sankaram, A.	1966	A laboratory Manual for Agricultural Chemistry. Asian publishing House, Bombay.
Satyanarayana, K.V.S. Swaminathan, K. and Viswanath, B.	1946	Comparative studies on Indian Soils carbon and nitrogen status of Indian soils and their profiles. Ind. J. Agric. Sci. 16: 1946.

Sen, A.T. Ashutosh, and Bhupendra Chandra Deb	1941	Laterite and Red Soils of India II. <u>Ind. J. Agri. Sci.</u> <u>XI</u>: 617.
Sen, A.T. Deb. B.S. and Bose, S.K.	1949	Potassium Status and availability to Crops of non exchangeable potassium in some Indian Red and laterite soils. <u>Soil Sci.</u> <u>68</u>: 291-293.
Shewan, J.M.	1938	Quoted by Russel. Soil conditions and plant growth. Longmans Green and Co. Ltd.
Sievers, F.T. and Holtz, H.F.	1923	The influence of precipitation on soil composition and soil organic matter maintenance. <u>Wash. Agric. Expt. Sta. Bull.</u> <u>176</u>: 1-30.
Sinha, S.D. Verma, R.P. Lall, A.L.	1957	A study of the morphology of some of the red soils of Ranchi District in relation to the topography of the land. <u>J. Ind. Soc. Soil. Sci.</u> <u>6</u>: 956-972.
Synghal, K.N.	1960	Characteristics of fifty Alberta soils. <u>J. Ind. Soc. Soil. Sci.</u> <u>8</u>: 77-83.
Thomas, K.M.	1964	Studies on some forest soil of Kerala. <u>Thesis submitted to and accepted by the University of Kerala.</u>
Tsuneo Tamura	1956	Physical, Chemical and mineralogical properties of Brown podzolic soils in Southern New England. <u>Soil. Sci.</u> <u>81</u>: 1-6.

Ukyl, A.C. Vyas, N.D. and Viswanath, B.	1944	Comparitive studies on Indian Soils II. Composition of clays from soil profiles. <u>Ind. J. Agric. Sci. 14:</u> 345-363.
Unnikrishnan, K	1961	The effect of rainfall and elevation on the properties of laterite soils. <u>Dissertation submitted to and accepted by the University of Madras.</u>
Vander Merwe, C.R.	1935	Grey ferruginous laterite soils Trans.3. Int. Carg. <u>Soil. Sci. 1</u>: 303-306.
Vanzijl, J.P.	1934	Soil problems of South Africa <u>Soil. Res. 4:</u> 160-167.
Vijay Chandran, P.K.	1963	Effect of Elevation and Rainfall on forms of principal plant nutrient elements in Kerala Soils. <u>Dissertation submitted to and accepted by the University of Madras.</u>
Viswanath, B. Ukyl, A.C.	1944	Comparitive studies on Indian soils Regional and environmental factors associated with Indian Soils. <u>Ind. J. Agric. Sci., 14:</u> 333-334.
Walker, T.W. Adams, A.F.R.	1958	Studies on soil organic matter 2. Influence of increased leaching at various stages of weathering on levels of Carbon, Nitrogen, and organic and total phosphorus. <u>Soil. Sci. 87</u>: 1-10.

Wilcox 1939 Soil moisture studies I. Some factors affecting the moisture holding capacity and its determination. Sci. Agric. 20: 140-149.

Wild, A. 1961 A pedological study of phosphorus in twelve soils derived from granite. Aust. J. Agric. Res. 12: 286-299.

Wohltmann, F. 1901 Quoted by Das, S. in Vertical distribution of phosphate in Calcareous Soils. Ind. J. Agric. Sci., 16: 164-168.

Yadav, J.S.P. Pathak 1963 Phosphorus status of certain forest soils of India. J. Ind. Soc. of soil Sci. 11: 181-187.

* Originals not seen