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Contents

PREFACE

Sustainable crop production rests heavily on the management of soil and water resources which have to be utilized optimally to obtain food, fodder, fiber, nutrition and environmental security for the future generation. Scientific management of land and water resources both under irrigated and rainfed farming requires a thorough understanding of the hydrological properties, water retention characteristics, available water capacities and water transmission characteristics of the soils. Preparation of any management strategy for water conservation, irrigation scheduling, drainage and solute migration, and development of various hydrological models require basic information on hydro-physical properties of soil. Suitable management practices can be formulated with the knowledge of water storage capacity of soil to minimize the risks of crop failure. Information on the hydro-physical properties of Orissa soils is meager. A systematic study of these properties and their water management implications has been a long felt need. This has now been achieved through the researches conducted at Water Technology Centre for Eastern Region, Bhubaneswar and is presented in the form of this Bulletin. This information may help in formulation of improved water management strategies and contingency crop planning for irrigated as well as unirrigated areas in this region.

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We sincerely hope that this bulletin will be of use to the researchers, developmental agencies, farmers and to all those who are interested in the management of soil and water in this region.

Ravender Singh
D. K. Kundu
H. N. Verma

EXECUTIVE SUMMARY

Knowledge of hydro-physical characteristics of soil is essential for formulating improved water management strategies and contingency crop planning for irrigated as well as unirrigated areas. Since information on this aspect is not available for Orissa soils, an attempt was made to generate information on hydro-physical characteristics of dominant soil subgroups of Orissa.

The state of Orissa, covering a geographical area of 15.57 million ha, lies in the tropical belt of the eastern region of India between 17^0 47′ to 22^0 33′ N latitude and 81^0 31′ to 87^0 30′ E longitude. The soils of Orissa have developed mainly through the interplay of relief, parent material and climate. The biotic features, mainly the natural vegetation, follow the climatic patterns. According to "Soil Taxonomy" (7th approximation), Orissa soils are classified under 4 orders, 10 suborders, 17 great groups and 41 subgroups of which 21 subgroups are dominant. Inceptisol is the dominant soil order covering 48.8% area of the state, followed by Alfisol (33.52%), Entisol (10.16%) and Vertisol (5.52%), respectively.

Inceptisol: Vertic Haplaquept, Aeric Haplaquept, Typic Tropaquept, Vertic Tropaquept, Aeric Tropaquept, Typic Ustochrept, Vertic Ustochrept and Typic Ustropept are the dominant soil subgroups under this order. Vertic Haplaquept, Typic Tropaquept, Aeric Tropaquept and Typic Ustochrept have clay texture with clay content varying from 42 to 56 per cent. The remaining soils, viz; Typic Ustropept, Vertic Tropaquept, Aeric Haplaquept and Vertic Ustochrept are sandy loam to sandy clay loam with clay content ranging from 17 to 34 per cent. Clay content in the soils generally increased with depth indicating movement of clay from surface to subsurface layers. Bulk density of the soils varied from 1.38 to 1.55 Mg m^{-3}. In general, all Inceptisols were low in organic carbon content. Organic carbon content varied from 0.03 to 0.69 per cent. All the soil subgroups were non-calcareous in nature and their $CaCO_3$ content varied from 0.1 to 2.2 per cent. CEC varied from 7.48 to 48.72 me/100g. Soils of this subgroup were slightly acidic to neutral in reaction and free from salt problem.

ψ-θ relationship, conductivity and diffusivity of the soils suggest that frequent irrigations using small amount of water each time will be required to improve use efficiency of water applied to Vertic Tropaquept, Vertic Ustochrept, Typic Ustropept and Aeric Haplaquept. Drip or sprinkler irrigation will prove useful to improve use efficiency of applied water and increase crop yield in these subgroups. Application of medium to heavy irrigation at long intervals, however, may be practiced in Aeric Tropaquept, Typic Tropaquept, Vertic Haplaquept and Typic Ustochrept for higher water use efficiency without any adverse effect.

In Typic Ustochrept, Vertic Haplaquept, Typic Tropaquept and Vertic Tropaquept adoption of suitable management practices for *in situ* conservation of water will be necessary to improve water use efficiency.

Alfisol: Typic Haplustalf, Typic Paleustalf, Ultic Paleustalf, Kandic Paleustalf, Rhodic Paleustalf, Typic Rhodustalf, Typic Ochraqualf and Aeric Ochraqualf are the dominant soil subgroups under this order. Texture of these soils ranged from sandy loam to clay, with clay content varying from 17.3 to 56 per cent. Highest bulk density was observed in Ultic Paleustalf and the lowest was observed in Rhodic Paleustalf.

Organic carbon (OC) content in these soils generally decreased with depth. Highest OC content was observed in Typic Haplustalf, where it varied from 0.21 to 0.60% and the lowest was observed in Rhodic Paleustalf. pH_2 ranged from 5.2 to 6.98 in 0-15 cm soil layer and from 6.2 to 7.3 in 120-150 cm soil layer. Data on electrical conductivity showed that all the soils were free from salinity problem. They were noncalcareous in nature with $CaCO_3$ content varying from 0.3 to 2.3%. The highest CEC was observed in Typic Ochraqualf and the lowest in Ultic Paleustalf.

Highest saturated hydraulic conductivity was observed in Ultic Paleustalf and the lowest in Typic Ochraqualf. At 0.033 MPa, maximum water was retained by Typic Ocharaqualf and the lowest by Ultic Paleustalf. Similar observations were recorded for 1.5 MPa. Available water content was maximum in Typic Haplustalf followed by Aeric Ochraqualf and Typic Ochraqualf. Available water content was minimum (0.110-0.1124 $cm^3 cm^{-3}$) in Ultic Paleustalf.

Highest penetrability and intrinsic penetrability values were found in Typic Paleustalf and the lowest in Typic Ochraqualf. Highest values of sorptivity were observed in Typic Paleustalf followed by Rhodic Paleustalf and Ultic Paleustalf. Sorptivity was the lowest in Typic Ochraqualf. Highest weighted mean diffusivity as well as intrinsic weighted mean diffusivity were found in Typic Paleustalf. While the lowest weighted mean diffusivity (2.970×10^{-8}m/s) as well as intrinsic weighted mean diffusivity (4.069×10^{-10}m) was found in Typic Ochraqualf.

Light and frequent irrigation and use of mulches will prove useful to improve use efficiency of applied water in Ultic Paleustalf, Kandic Paleustalf, Typic Rhodustalf, Rhodic Paleustalf and Typic Paleustalf. Frequency of irrigation in these soils may be reduced through use of mulches. In these subgroups, use of drip or sprinkler irrigation will prove useful for increasing water use efficiency and crop yields. Medium to heavy irrigation applied at long intervals will be effective in Typic Haplustalf, Aeric Ochraqualf and Typic Ochraqualf to improve use efficiency of applied water and crop productivity.

In situ conservation of water will be necessary to improve water use efficiency in Typic Ochraqualf, Typic Haplustalf, Kandic Paleustalf and Aeric Ochraqualf. Modification of texture with addition of appropriate amendments will help in improving water use efficiency and crop productivity of these soil subgroups.

Entisol: Typic Ustorthent, Lithic Ustorthent, Aeric Fluvaquent and Typic Ustipsamment are the dominant subgroups of this order. Aeric Fluvaquent was clay loam to clay in texture with clay content ranging from 34.26 to 49.16%. Typic Ustorthent and Lithic Ustorthent were loam to clay loam in texture with clay content varying from 26.2 to 38.6%. Typic Ustipsamment was loamy sand to sandy clay loam in texture with clay content ranging from 9.66 to 26.02%. Highest bulk density was observed in Typic Ustipsamment and the lowest in Aeric Fluvaquent. Generally, pH increased with soil depth. Data on electrical conductivity showed that all sub-groups except Aeric Fluvaquent were free from salinity problem. EC_2 of the Aeric Fluvaquent profile varied from 1.35 to 3.80 dS/m indicating moderate level of salinity. In general, all subgroups were low in organic carbon content (OC). All the sub-groups were noncalcareous in nature with their $CaCO_3$ content varying from 0.10 to 2.6 per cent. Cation exchange capacity (CEC) of the soil sub-groups varied widely. CEC was the highest in Aeric Fluvaquent (21.79 to 32.53 me/100g) and the lowest in Typic Ustipsamment (3.92 to 13.63 me/100g).

Highest saturated hydraulic conductivity (4.428 cm/hr) was observed in Typic Ustipsamment and the lowest (0.003cm/hr) in Aeric Fluvaquent. At 0.033 MPa, maximum water was retained by Aeric Fluvaquent (0.399 to 0.578 cm^3 cm^{-3}) and the minimum water retention was exhibited by Typic Ustipsamment. Similar trends of water retention by these soil subgroups were observed at 1.5 MPa. Available water content was the highest in Aeric Fluvaquent and the lowest in Typic Ustipsamment.

Application of FYM and green manure to Typic Ustipsamment and green manure with lime or lime sludge from paper mills to Typic Ustorthent will be necessary to improve water use efficiency. Aeric Fluvaquent showed moderate salinity and low penetrability, intrinsic penetrability, sorptivity, weighted mean diffusivity and intrinsic weighted mean diffusivity. Although this subgroup had high moisture retention and available water capacity, it will be unable to supply sufficient water to plants because of their low transmission characteristics. Frequent supply of water to lower the suction is required for successful crop production in this subgroup. Adoption of proper water conservation practices will be necessary for Typic Ustorthent to improve water use efficiency. Medium irrigation applied at appropriate intervals will be effective in this type of soil. Lithic Ustorthent subgroup has shallow soils. Adoption of suitable soil and water conservation practices will be necessary to improve water use efficiency and productivity of these soils. Shallow rooted crops and light to medium irrigation applied at appropriate interval will be effective.

Vertisol: Only one soil sub-group, viz. Typic Chromustert is found under this order. Typic Chromustert was clay in texture with clay content ranging from 41.5 to 51.5 per cent. Bulk density varied from 1.36 to 1.44 Mgm^{-3}. The soil was free from any salt problem. pH_2 varied from 6.8 to 8.3. Subsoil was slightly alkaline in nature. Organic carbon content varied from 0.08 to 0.57 per cent. $CaCO_3$ content ranged from 1.5 to 3.2 per cent and CEC ranged from 21.75 to 34.15 me/100 g.

Water holding capacity of these soils is high but transmittivity is very low, hence plants suffer from drought even at moderate soil moisture level. Incorporation of organic materials like rice straw, saw dust, molasses, etc. would improve soil aggregability and water movement in these soils. Medium to heavy irrigation applied at long intervals will be effective. Problem of water logging is more in this subgroup, hence provisions for proper drainage are essential for successful farming in these soil types.

Prediction of water storage capacity of the soil profiles: Moisture retention at field capacity and wilting point, and available water in these soils was influenced by two sets of factors influencing in opposite direction. While one set of factors, viz. silt, clay, organic carbon, calcium carbonate and cation exchange capacity influenced positively, the other set of factors, viz. sand and bulk density influenced negatively. Consequently, available water content was also influenced by the same set of factors and in a similar manner.

For prediction of available soil water: sand, silt and cation exchange capacity accounted for 67.3 per cent variation; sand, silt, clay, bulk density, organic carbon and calcium carbonate together contributed only 63.6 per cent; and sand and silt together accounted for 62.5 per cent variation. Hence, available water can not be predicted as accurately as water content at field capacity and wilting point. It was better to estimate available water using the predicted values of field capacity and wilting point.

1. INTRODUCTION

Knowledge of hydro-physical characteristics of soils is essential for scheduling agricultural operations and it assumes particular significance in the management of soil and water. Preparation of any management strategy in water conservation, irrigation scheduling, drainage and solute migration, and development of various hydrological models require basic information on soil hydraulic properties. Efficient use of available water resources for optimization of crop productivity both under irrigated and rainfed farming require a thorough understanding of the hydrological properties of soil like water retention characteristics, available water capacities and water transmission characteristics of soils. Suitable management practices can be adopted to minimise the risks of poor crop yields and crop failure with the knowledge of water storage capacity of soil in addition to water availability.

Agriculture in the state of Orissa is predominantly rainfed. Although it receives high rainfall and has good ground water resource, farmers grow only one crop in rainy season and most of the fields lie barren during post rainy season in rainfed areas. In canal command areas, use efficiency of applied irrigation water is very low, often 30% or less (Pande and Reddy 1988). The state has good scope of irrigation expansion and rain water conservation *in situ*. Information on the hydro-physical properties of soil may help in formulating improved water management strategies and contingency crop planning for irrigated as well as unirrigated areas for improving the prospect of yield enhancement and stabilization in this region. Since information on this aspect is not available for Orissa soils, an attempt was made to generate information on soil water retention characteristics, available water capacities and water transmission characteristics of dominant soil subgroups.

Soil erosion has been identified as a potential threat to sustainability of the livelihood system of the people in eastern India. In the eastern region, Orissa is reported to have the largest land area affected by soil erosion. Adequate base line information on erodibility of different soil types of Orissa was not available for devising appropriate erosion control measures. Erosion indices were therefore determined for surface as well as subsurface layers of the soil profiles, and they were related to various physicochemical properties of the soils.

2. AGRO-CLIMATIC CONDITIONS OF ORISSA

The state of Orissa, covering a geographical area of 15.57 million ha, lies in the tropical belt of the eastern region of India between 17° 47′ to 22° 33′ N latitude and 81° 31′ to 87° 30′ E longitude. The state is bounded by the states of Jharkhand at the north, West Bengal at the north-east, Chhattishgarh at the north-west and Andhra Pradesh at the south-west. The east of the state is bounded by Bay of Bengal with a coast-line of 480 km. It is the tenth largest state of India in terms of area. Based on the existing relief features, the state can be broadly divided into 4 physiographic divisions: (a) northern plateau, (b) central table land, (c) eastern ghat, and (d) coastal plains.

The northern plateau is a continuation of Chhotanagpur plateau of Jharkhand and includes the districts of Mayurbhanj, Keonjhar, Sundargarh and Pallahara sub-division, and northern parts of Talcher sub-division of Dhenkanal district, small parts of north west of Jajpur sub-division of Cuttack district, Nilgiri sub-division of Balasore district and Deogarh-Kuchinda, Jharsuguda and northern parts of Rairakhol sub-division of Sambalpur district. About 23% of the total area of the state comes under this region. This region covers watersheds of the river Brahmani, Baitarani, Salandi and Budhabalanga.

The central table land consists of the districts of Bolangir, the southern parts of Dhenkanal district, northern parts of Boudh sub-division of Phulbani district, Athagarh sub-division of Cuttack district, Sambalpur and southern part of Rairakhol sub-division of Sambalpur district. It consists chiefly of the Mahanadi basin with the rivers Jira, Ong and Tel. In the extreme north-east lies a part of the catchment of Brahmani.

The eastern ghat region consists of hill ranges which belong to the main-line of eastern ghats along with some plains and valleys lying between them. This is the largest of the 4 regions, covering about 36% of the total area of the state and consists of the districts of Koraput, Kalahandi and Phulbani except the northern part of Boudh sub-division, the western and extreme northern portion of Ganjam disrict. The region has the river Tel and its tributaries in the north and Bansadhara and Nagavali in the south-east. In the south-western portion of the region flows the Machhakund which is a tributary to Silera. The southern portion of Koraput sub-division is a plateau with elevation of more than 610 m MSL. A large part of Kalahandi district with an elevation of 274 m lies between the river Tel in the north and the Jeypore plateau in the south and through which passes the Hatinala. Most of the cultivated areas are slopy uplands.

The coastal region runs from north to south having a width between 24 and 72 km from the sea-coast in the districts of Balasore, Cuttack and Puri. The eastern part of Ganjam district also comes within this range. The coastal plain is characterized by a number of deltas mainly formed by the rivers Subarnarekha, Mahanadi, Brahmani and Baitarani. This zone covers about 18% of the total area of the state.

The state lies in sub-tropical belt of medium pressure. The summer is hot and dry and is followed by wet and humid monsoon (rainy season) which lasts for about four months. The autumn is pleasant. The winter is short and mild. The state, in general, has the climate characterised by high temperature and medium rainfall. Topography, however, modifies the local climate greatly. The four seasons prevailing in the state are:

2.1 Hot and dry summer season (March, April and May)

Maximum temperature during this period ranges from 34.8 to 38.0°C and mean minimum temperature from 23.0 to 24.0°C. Maximum temperature of 42°C occurs in the month of May. Average duration of bright sunshine is 8.8. hours per day. Even though temperature runs high, the bright sunshine hours fall short of normal day length due to clouds of varying percentage.

2.2 Hot and humid wet season (June, July, August and September)

The monsoon sets in towards the second week of June. Rainfall intensifies during the months of July and August. For several days in July, the sky remains cloudy and the Sun is not seen. Average duration of bright sunshine falls to 3.7 hours per day. Temperature remains high with maximum of 35^{0}C and minimum of 24^{0}C. Due to high humidity the weather remains stuffy.

2.3 Autumn season (October and November)

During this period, mean maximum temperature runs between 31 and 32^{0}C and mean minimum temperature between 17 and 21^{0}C and weather remains bright. The sky remains clear and the average duration of bright sunshine increases to 7-8 hours per day.

2.4 Winter season (December, January and February)

The coldest month of year is December. Average minimum temperature is 13.2^{0}C and maximum temperature is 27.3^{0}C. The sky remains clear and average duration of the bright sunshine is 6 hours per day.

2.5 Rainfall

Major portion of rainfall in the state is received from the south-west monsoon which breaks in 2nd to 3rd week of June and continues till 1st week of October. Average rainfall of the state is 1497 mm of which about 1320 mm is received during the monsoon months spreading from June to September. Maximum rainfall is received in the month of August. An analysis of rainfall data for the state reveals a gradually declining trend in rainfall after 1950. During the decinnium 1960 to 1970 and the next, the rainfall averaged 1321 and 1319 mm, respectively. During the period from 1901 to 1975, there were 12 to 13 years of major droughts and equal number of floods. The frequency of drought has increased more than that of flood after 1950. Out of 13 years of drought during 1901 to 1975, 8 years were after 1950. Frequency of drought is more in the districts of Bolangir, Sambalpur, Sundargarh, Phulbani and Kalahandi which are the drought-prone areas of the state. During the period from 1950 to 1973 (24 years), dry spell for 7 to 10 days had occurred in six years in September and 10 years in October. December and January are the driest months. Till to-day the agriculture in the state is a gamble of monsoon. In the years of normal rainfall, distribution pattern of the rainfall controls crop yields. In the years of drought, failure of rain causes water scarcity; while in the years of excess rainfall, the amount and distribution of rainfall determine the nature and intensity of floods (Anonymous, 1989).

2.6 Temperature

The hot weather starts in the month of March, temperature starts rising in April and peaks in the month of May. The temperature rise during this period somewhat varies between the coastal districts along with the eastern ghat highland region and the rest of the state. In the western districts of Sundargarh, Sambalpur, Bolangir and Dhenkanal (central), maximum temperature attains around 42^{0}C in the month of May. In the coastal districts of Balasore, Cuttack, Ganjam and Puri, and in the eastern ghat high hills (Koraput), it is around 35^{0}C. With the onset of monsoon from July through October, the temperature falls. Thereafter it steadily decreases until the month of January when it records the lowest daily maximum and minimum temperature. Minimum winter temperature in the districts of Koraput, Phulbani, Kalahandi and Keonjhar is less compared to that in the remaining part of the state (Anonymous, 1989).

2.7 Land utilization pattern in Orissa (area in million ha)

Total geographical area	15.57
Reporting area for land utilization statistics	15.57
Forests	5.60
Fallow land other than current fallow	0.31
Current fallow	0.62
Cultivable waste	0.47
Miscellaneous crops	0.78
Pasture	0.62
Barren	0.47
Non agricultural use	0.78
Net area sown	5.92

Source: Sarkar *et al.*, 2000

2.8 Soils of Orissa: The soils of Orissa have developed mainly through the interplay of relief, parent material and climate. Biotic features, mainly natural vegetation follow the climatic patterns. According to Soil Taxonomy (7th Approximation), the soils are classified under 4 orders, 10 suborders, 17 great groups and 41 sub groups of which 21 sub groups are dominant. Inceptisols are the dominant soils covering 48.8% area of the state, followed by Alfisols (33.52%), Entisols (10.16%) and Vertisols (5.52%), respectively (Sarkar *et al.*, 2000).

3. METHODOLOGY

3.1 Method of sampling soil profiles: Profile soil samples were collected from twenty-one sites spread over 15 districts of Orissa, representing 21 dominant subgroups. The sampling sites are described in Table 1 and shown in Fig.1. Three soil profiles were dug for each site and samples were collected from 0-15, 15-30, 30-60, 60-90, 90-120 and 120-150 cm depth of each profile.

3.2 Determination of physicochemical properties of soils: Processed soil samples (< 2 mm size) were analysed for mechanical composition following International Pipette method. Bulk density was estimated on undisturbed samples collected with metal cores of 4.2 cm diameter and 5.8 cm height (Klute, 1986). Organic carbon content, calcium carbonate and cation exchange capacity of the soils were determined following standard procedures (Jackson, 1976).

3.3 Determination of water retention characteristics of soils: For determination of water retention, undisturbed soil samples were collected using metal cores of 5-cm diameter from all these depths. Water retention at different tensions was estimated by using pressure plate apparatus (Richards, 1965). Water retention at 10 kPa tension was considered as field capacity for light textured soils and that at 33 kPa tension for medium and heavy textured soils. Water retained between field capacity and wilting point was considered as available water. Profile water storage capacity of 5, 5-10, 10-15, 15-20 and 20 cm m^{-1} depth were categorized as very low, low, medium, high and very high, respectively (Rao and Prasadini, 1998). Regression analysis was done to develop equations for predicting water retention at field capacity, wilting point and available water.

3.4 Determination of diffusivity and hydraulic conductivity of soils: Horizontal infiltration experiments were carried out in plexiglass columns of 0.35 m length and 0.036 m diameter. Detailed description of the method is given in Singh *et al.* (2000) and Singh and Kundu (2001). The columns were prepared by joining plexiglass segments placed one over another

Table 1. Description of soil sampling sites

Soil order	Soil sub-group	Site No.	Taluka	District	Situation of soil sampling site	
					N latitude	E longitude
Inceptisol	Aeric Tropaquept	1	Bhubaneswar	Khurda	20°14′ -20°24′	85°45′ -85°55′
	Aeric Haplaquept	2	Harvanga	Boudh	20° 30′ -20°40′	84°35′ -85°45′
	Typic Ustochrept	3	Tentulikhanti	Nowrangpur	19°15′ -19°26′	82°25′ -82°35′
	Vertic Haplaquept	4	Dhenkanal	Dhenkanal	30°35′ -30°45′	85°35′ -85°40′
	Vertic Tropaquept	5	Begunia	Khurda	20°10′ -20°20′	85°24′ -85°40′
	Typic Ustropept	6	Polosara	Ganjam	19°39′ -19°50′	84°46′ -84°56′
	Typic Tropaquept	7	Basta	Balasore	21°36′ -21°45′	87°09′ -87°21′
	Vertic Ustocrept	8	Kamakhyanagar	Dhenkanal	20°48′ -20°60′	85°30′ -85°40′
Alfisol	Ultic Paleustalf	9	Bhanjanagar	Ganjam	19° 56′ -20°10′	84°27′ -84°40′
	Typic Paleustalf	10	Sorada	Ganjam	19°40′ -19°48′	84°15′ -84°25′
	Rhodic Paleustalf	11	Nayagarh	Nayagarh	20°02′ -20°10′	85°08′ -85°19′
	Typic Rhodustalf	12	Phulabani	Phulabani	20°28′ -20°40′	84° 01′ -84°16′
	Typic Ochraqualf	13	Kendujhargarh	Kendujhar	21°35′ -21°45′	85°35′ -85°41′
	Aeric Ochraqualf	14	Murda	Mayurbhanj	21°45′ -21°55′	86°50′ -86°58′
	Typic Haplustalf	15	Jamankira	Sambalpur	21° 32′ -21°42′	84°15′ -84°22′
	Kandic Paleustalf	16	Semiliguda	Koraput	18°42′ -18°49′	82°38′ -82°47′
Entisol	Aeric Fluvaquent	17	Erasama	Jagatsinghpur	20°08′ -20°20′	86°15′ -86°25′
	Typic Ustipsamment	18	Chatrapur	Ganjam	19°15′ -19°26′	84°48′ -84°56′
	Typic Ustorthent	19	Anandpur	Kendhujhar	21°20′ -21°30′	86°35′ -86°44′
	Lithic Ustorthent	20	Sohela	Bargarh	21°14′ -21°24′	83°16′ -83°28′
Vertisol	Typic Chromustert	21	Bhawani-patana	Kalahandi	19°50′ -19°09′	83°05′ -83°25′

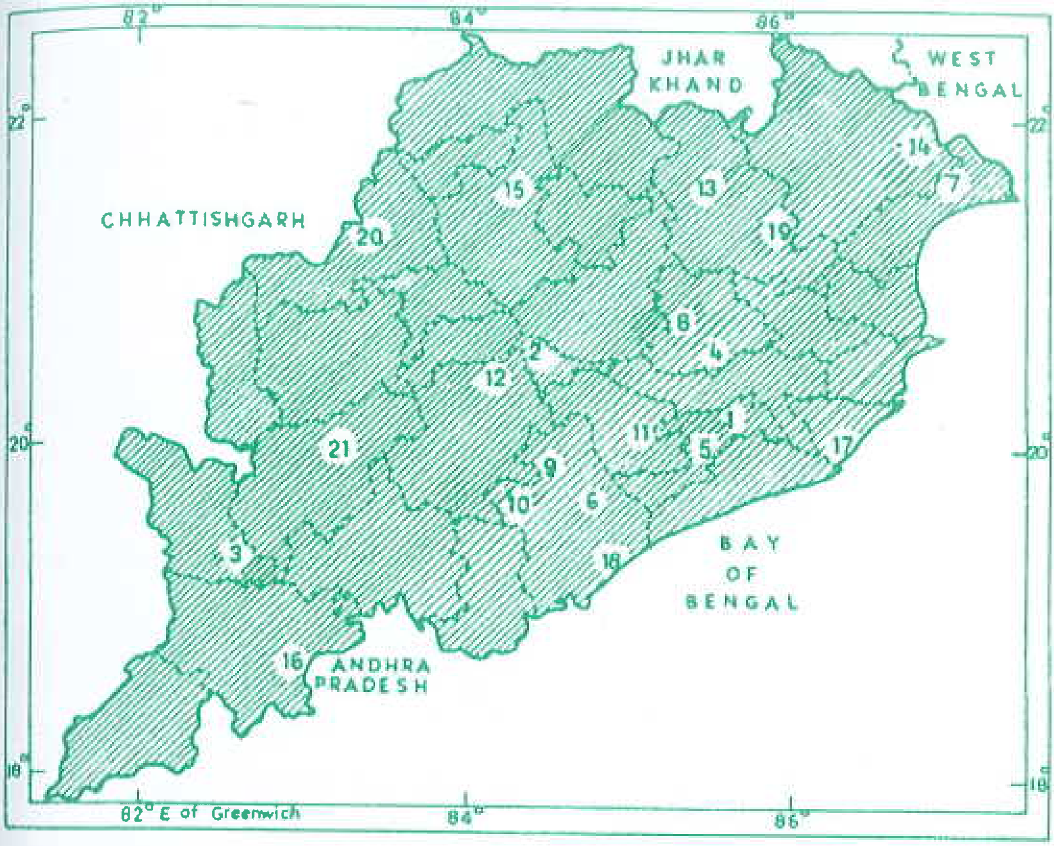

Fig. 1 : Map of Orissa showing the sampling sites of soil profiles described in Table 1.

in opposite direction keeping the eccentric holes in them upright and fitted with a coarse sintered glass plate at one end. They were filled as uniformly as possible with soil samples at desired bulk density. For achieving the desired bulk density, weighed soil was filled in each segment of the columns one by one on a vibrator. Columns were placed horizontally on a wooden stand and water was introduced at the inlet end from Marriottee tube at a constant suction of 0.2 kPa of water. Water entering the column was measured volumetrically and distance from water source to the wetting front was visually observed. After completion of infiltration, the column was sectioned into 1 cm segments and water content in the soil segments determined gravimetrically. The infiltration tests were replicated thrice with each soil.

Soil water diffusivity functions, D (θ) were calculated from experimental water content profiles using relationship given by Bruce and Klute (1956):

$$D(\theta) = -1/2t \, . \, dx/d\theta \int_{\theta i}^{\theta s} x\,d\theta \quad \ldots\ldots\ldots\ldots \quad (1)$$

where D (θ) is soil water diffusivity at the volumetric water content θ, θi is initial water content, θs is water content at saturation, x is distance from the water source and 't' is the duration of water entry into the column.

Unsaturated hydraulic conductivity, K(θ) was worked out from the following relationship:

$$K(\theta) = D(\theta)\, d\theta/dh \quad \ldots\ldots\ldots\ldots \quad (2)$$

where h is soil water suction and dθ/dh is slope of the soil water retention curves obtained by using pressure plate apparatus.

Weighted mean diffusivity of water in soil (D) was worked out from the following equation given by Crank (1956):

$$D = 5/3\, [\, 1/(\theta s - \theta i)]^{5/3} \int_{\theta i}^{\theta s} D(\theta) \, . \, (\theta - \theta i)^{2/3}\, d\theta \quad \ldots\ldots\ldots\ldots \quad (3)$$

Intrinsic weighted mean diffusivity (Di) was calculated from the weighted mean diffusivity by using following relationship:

$$Di = \eta/(\gamma \cos H).\, D \quad \ldots\ldots\ldots\ldots \quad (4)$$

where η is viscosity, γ is surface tension, and H is the angle of contact between water and soil.

Penetrability (P), intrinsic penetrability (Pi) and sorptivity (S) were calculated by using following relationships:

$$P = x/t^{1/2} \quad \ldots\ldots\ldots\ldots \quad (5)$$

$$P = Pi\, (\gamma/\eta \cos H)^{1/2} \quad \ldots\ldots\ldots\ldots \quad (6)$$

$$S = I/t^{1/2} \quad \ldots\ldots\ldots\ldots \quad (7)$$

where x is distance of wetting front and I is cumulative infiltration.

3.5 Determination of soil erodibility:

Soil erodibility can be evaluated by the measurement of soil loss in run-off plots, which is quite expensive, time consuming and has been feasible only for a few soil types. Several empirical equations have been suggested from time to time to assess soil erodibility. These equations are also very cumbersome as they require determination of many parameters. Erosion index (EI) is a simple and reliable parameter (Sahi *et al.*, 1977; Gupta *et al.*, 1998) for determining soil erodibility. It provides a numerical expression of the potential for a soil to erode. Higher the index value, the greater will be the investment needed to maintain the sustainability of the soil. Erodibility of surface as well as subsurface soils belonging to 4 orders and 21 subgroups in Orissa was assessed by using erosion index.

Erosion index:

Erosion index was computed from the following relationship described by Sahi *et al.*, (1977):

Erosion index = Dispersion ratio/(clay/0.5 water holding capacity)

Dispersion ratio was calculated from the following relationship described by Middleton (1930):

Dispersion ratio = 100 (silt + clay dispersible in water)/ (total silt + clay)

Dispersible silt + clay was determined by dispersing 25 g soil in 1000 ml distilled water without adding any dispersing agent, shaking end to end for 20 times and pipetting out 20 ml of soil suspension from 10 cm depth.

4. RESEARCH FINDINGS

4.1 Soil Order: INCEPTISOL

These soils represent the early stage in soil formation which is beyond that of entisol but still short of the degree of development found in alfisol. Inceptisols are usually not dry and have developed rather recently owing to the alteration of the parent material but without much leaching and accumulation of material in the subsoil. The soils have too weak profile development. These soils are formed in low, rolling parts of the landscape in and around steep mountain fronts. In sequences of alluvial terraces they form at intermediate positions between Entisols nearest the stream and other developed soils farther away from the stream. Under this order, 3 suborders are observed. They are Aquepts, Ochrepts and Tropepts.

Aquepts: They have an aquic moisture regime and are artificially drained. If there is mottling, chroma is 2 or less; and if there is no mottling, chroma is 1 or less. There is an ochric epipedon that is underlain by a cambic horizon. They may have an SAR 13 or ESP 15 in half or more of the soil profile and that decreases with depth below 50 cm. Ground water is seen within 1 m of the surface at some time of the year.

Ochrepts: These are mainly light coloured, brownish, more or less freely drained inceptisols formed on nearly level to steep surface. They have an ochric epipedon or an ambric or mollic epipedon that is less than 25 cm. They have chroma too high than aquepts and do not have an aquic moisture ragime.

Tropepts: These are inceptisols with an ochric epipedon and cambic horizon. They are brownish to reddish, more or less freely drained. These soils are formed on moderate to steep slopes in the humid tropics particularly in hilly tropical areas. It may have a mollic epidedon with 35% montmorillonitic clay but the underlying cambic horizon has < 50 % base saturation (by NH_4OAc).

There are 2 great groups under the suborder Aquept, viz., Haplaquept and Tropaquept; one under Ochrept, viz., Ustochrept; and one under Tropept, viz., Ustropept. Characteristics of these great groups are as follows:

Haplaquepts: These are light coloured grey Aquepts in midlatitudes, do not have fragipan or duripan, have ground water that stands at or near the surface for long periods but not throughout the year, have SAR < 13 and ESP < 15, and plinthite if present is <50% of matrix.

Tropaquepts: They are mostly grey at the surface and mottled in deeper layers. The groundwater table fluctuates but stands relatively high, formed in tropical regions with no plinthite, and have SAR<13 and ESP <15.

Ustochrepts: These are reddish or brownish, formed in sub humid to semi arid region. Most of them are calcareous at a shallow depth, and do not have duripan within 1 meter of the soil surface.

Ustropepts: These are base-rich Tropepts, formed mostly in sub-humid regions. They may be on steep slope and shallow over rock or may be formed on alluvium with gentle slopes. They usually have calcic horizon below a cambic horizon, and an ustic moisture regime.

The great groups Haplaquept, Tropaquept, Ustochrept and Ustropept have 2,3,2 and one dominating subgroup respectively as given below:

1. Vertic Haplaquept
2. Aeric Haplaquept
3. Typic Tropaquept
4. Vertic Tropaquept
5. Aeric Tropaquept
6. Typic Ustochrept
7. Vertic Ustochrept
8. Typic Ustropept

4.1.1 Physicochemical and hydrological characteristics:

Physicochemical and hydrological characteristics of Inceptisols are presented in Tables 2 to 9. Vertic Haplaquept, Typic Tropaquept, Aeric Tropaquept and Typic Ustochrept have clayey texture with clay content varying from 42 to 56 per cent. The remaining soils, viz., Typic Ustropept, Vertic Tropaquept, Aeric Haplaquept and Vertic Ustochrept are sandy loam to sandy clay loam with clay content ranging from 17 to 34 per cent. Clay content in the soils generally increased with depth indicating movement of clay from surface to subsurface layers. Bulk density of the soils varied from 1.38 to 1.55 Mg m^{-3}, depending upon their texture. The bulk density was higher for coarse fraction. Bulk density also increased as the depth of the soil increased in all the subgroups. In general, all Inceptisols were low in organic carbon content. Organic carbon content varied from 0.03 to 0.69 per cent. In all the subgroups, organic carbon content was higher in surface than in subsurface horizons/layers. All the soil subgroups were non-calcareous in nature and their $CaCO_3$ content varied from 0.1 to 2.2 per cent. Cation exchange capacity of the soils (CEC) varied widely depending upon their texture. Higher the fine fraction (clay), higher was the CEC of the soils. The CEC varied from 7.48 to 48.72 me/100g. The highest CEC was observed in Vertic Haplaquept and the lowest in Vertic Tropaquept. These soils (Inceptisols) were slightly acidic to neutral in reaction. pH_2 of the soils varied from 5.30 to 7.72 and EC_2 ranged from 0.06 to 0.60 dS/m indicating that they were free from salt problem.

Saturated hydraulic conductivity (Ks), water content at saturation (θs), water content at 0.033 and 1.5 MPa and available water content are presented in Tables 2b to 9b and soil water retention characteristics (ψ-θ relationships) are presented in Fig. 2a to 9a. At 0.033 MPa, highest water was retained by Typic Ustochrept followed by Vertic Haplaquept, Typic Tropaquept and Aeric Tropaquept. Water retention was lowest in case of Vertic Tropaquept (0.152 to 0.294 $cm^3 cm^{-3}$). At 1.5 MPa, highest amount of water was retained by Vertic Haplaquept and the lowest by Vertic Tropaquept. Highest available water at all the depths was found in Typic Ustochrept followed by Vertic Haplaquept, Typic Tropaquept and Aeric

Table 2(a): Physicochemical characteristics of Vertic Haplaquept

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	45.6	34.8	9.9	9.7	c	1.39	0.18	6.1	0.69	0.1	40.02
15-30	51.8	30.5	8.7	9.0	c	1.40	0.22	6.7	0.39	1.3	44.37
30-60	52.4	31.4	8.3	7.9	c	1.41	0.32	6.6	0.40	1.4	46.11
60-90	55.2	28.4	8.1	8.3	c	1.42	0.24	6.8	0.33	1.4	48.72
90-120	55.8	25.4	8.5	10.3	c	1.43	0.29	6.8	0.33	0.8	48.72
120-150	52.7	30.5	8.4	8.4	c	1.45	0.16	6.9	0.19	0.8	43.5

Table 2 (b): Hydraulic characteristics of Vertic Haplaquept

Soil depth (cm)	Ks (cm/hr)	θs (cm³/cm³)	θ (cm³/cm³) at 0.033 MPa	θ(cm³/cm³) at 1.5 MPa	Available water content (cm³/cm³)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.021	0.632	0.452	0.231	0.221	7.400×10^{-4}	8.667×10^{-5}	2.760×10^{-4}	7.216×10^{-7}	9.885×10^{-9}
15-30	0.015	0.659	0.521	0.279	0.242	1.945×10^{-4}	2.277×10^{-5}	1.296×10^{-4}	2.464×10^{-8}	3.376×10^{-10}
30-60	0.014	0.661	0.540	0.288	0.252	2.994×10^{-4}	3.506×10^{-5}	1.361×10^{-4}	6.543×10^{-7}	8.964×10^{-9}
60-90	0.013	0.688	0.542	0.298	0.244	5.447×10^{-4}	6.415×10^{-5}	3.062×10^{-4}	2.097×10^{-7}	2.873×10^{-9}
90-120	0.012	0.648	0.533	0.312	0.221	2.654×10^{-4}	3.108×10^{-5}	1.293×10^{-4}	4.181×10^{-8}	5.728×10^{-10}
120-150	0.011	0.632	0.557	0.315	0.242	5.473×10^{-4}	6.410×10^{-5}	2.554×10^{-4}	2.866×10^{-7}	3.926×10^{-9}

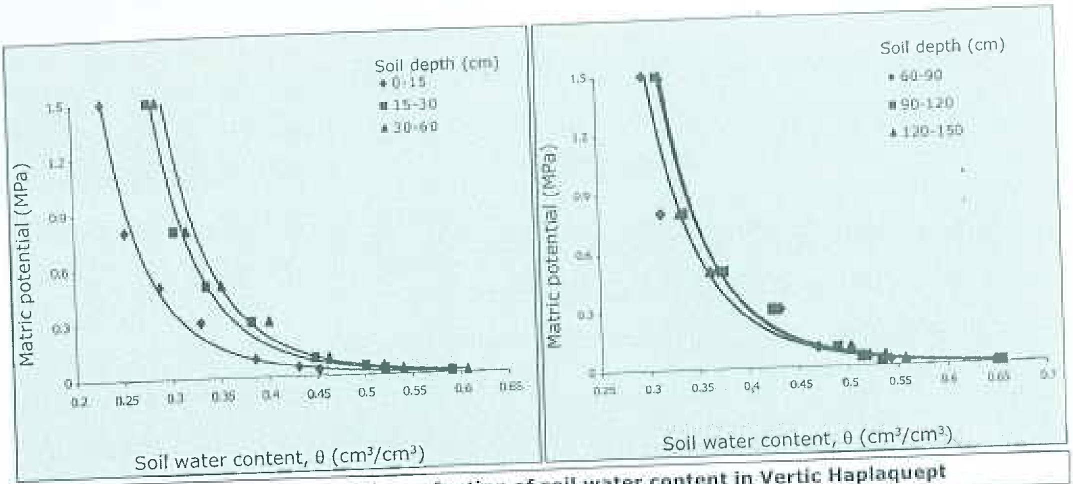

Fig.2a. Matric potential as a funtion of soil water content in Vertic Haplaquept

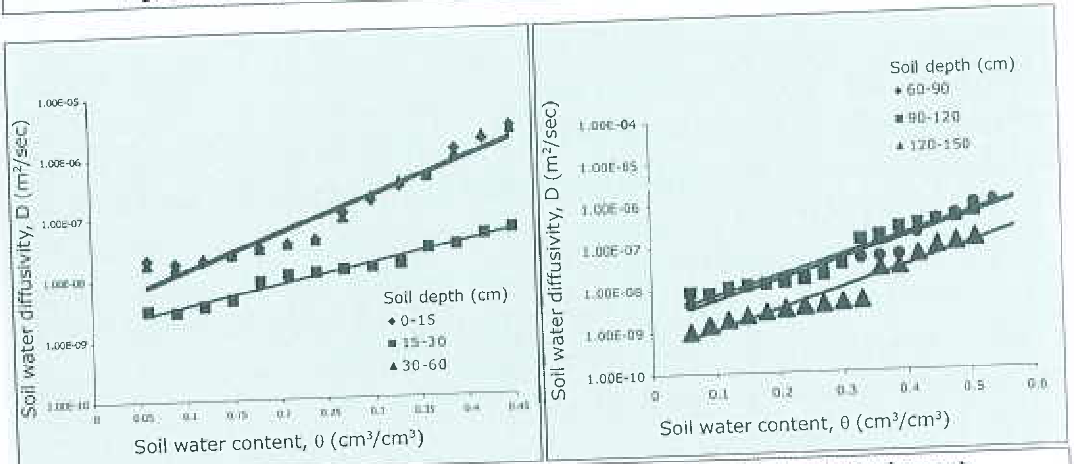

Fig.2b. Soil water diffusivity as a function of water content in Vertic Haplaquept

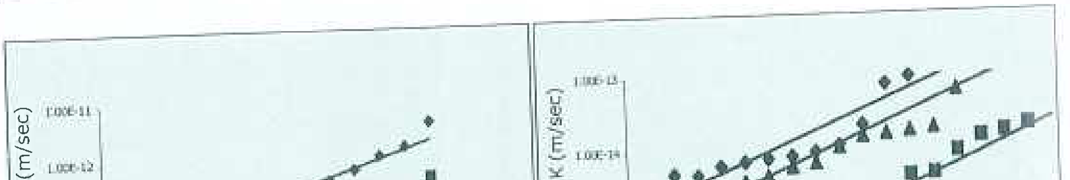

Fig.2c. Hydraulic conductivity as a function of water content in Vertic Haplaquept

Table 3 (a): Physicochemical characteristics of Aeric Haplaquept

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC$_2$ (dS/m)	pH$_2$	OC (%)	CaCO$_3$ (%)	CEC (me/100g)
0-15	18.9	15.7	24.6	40.8	Sl	1.45	0.11	5.8	0.48	0.4	10.93
15-30	28.5	14.8	12.2	44.5	Scl	1.46	0.09	6.2	0.40	0.6	15.25
30-60	36.2	15.7	6.3	41.8	Sc	1.48	0.09	6.1	0.23	0.6	16.00
60-90	35.5	14.9	5.9	43.7	sc	1.48	0.09	6.4	0.13	0.8	21.87
90-120	41.2	15.8	7.2	35.8	c	1.49	0.14	6.4	0.16	0.8	36.38
120-150	41.8	14.8	8.2	35.2	c	1.50	0.13	6.5	0.17	1.0	35.70

Table 3 (b): Hydraulic characteristics of Aeric Haplaquept

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.146	0.508	0.314	0.101	0.213	2.250x10^{-3}	2.635x10^{-4}	7.229x10^{-4}	1.729x10^{-6}	2.300x10^{-8}
15-30	0.148	0.561	0.297	0.102	0.195	2.114x10^{-3}	2.476x10^{-4}	7.229x10^{-4}	2.600x10^{-6}	3.500x10^{-8}
30-60	0.274	0.566	0.332	0.130	0.202	2.388x10^{-3}	2.797x10^{-4}	8.798x10^{-4}	3.403x10^{-6}	4.600x10^{-8}
60-90	0.317	0.571	0.360	0.173	0.187	2.380x10^{-3}	2.788x10^{-4}	8.400x10^{-4}	3.349x10^{-6}	4.500x10^{-8}
90-120	0.370	0.570	0.409	0.163	0.246	1.821x10^{-3}	2.133x10^{-4}	7.408x10^{-4}	1.313x10^{-6}	1.800x10^{-8}
120-150	0.361	0.581	0.389	0.167	0.222	1.924´10^{-3}	2.534x10^{-4}	7.689x10^{-4}	1.731x10^{-6}	2.308x10^{-8}

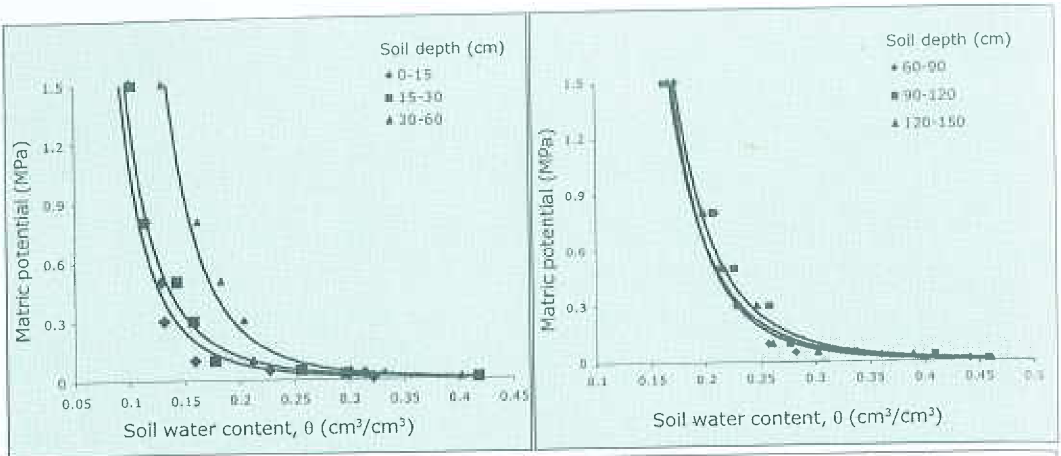

Fig.3a. Matric potential as a funtion of soil water content in Aeric Haplaquept

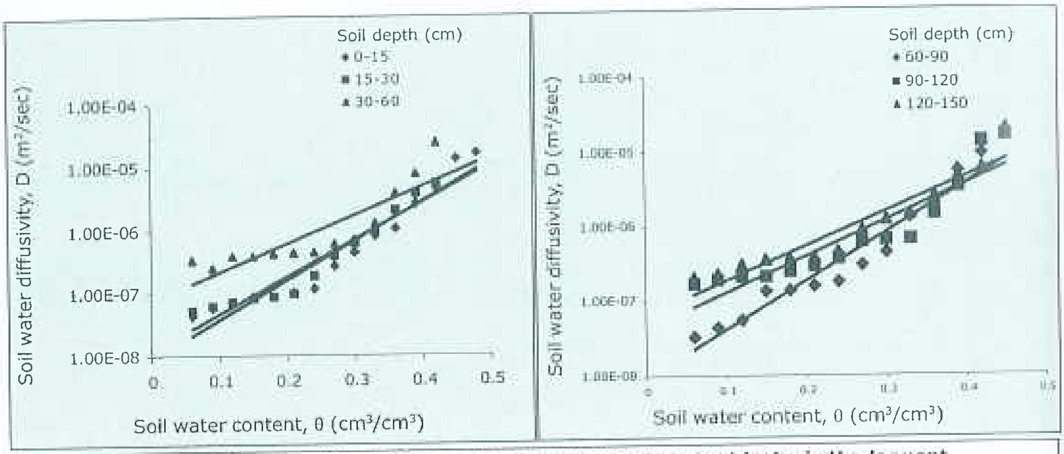

Fig.3b. Soil water diffusivity as a function of water content in Aeric Haplaquept

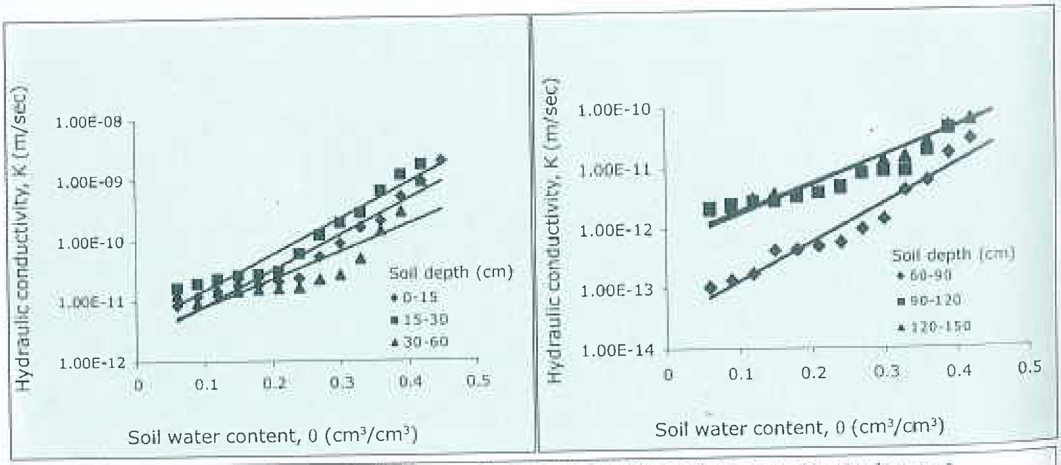

Fig.3c. Hydraulic conductivity as a function of water content in Aeric Haplaquept

Table 4(a): Physicochemical characteristics of Typic Tropaquept

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	42.8	47.6	5.7	3.9	c	1.38	0.10	7.0	0.51	2.2	16.53
15-30	44.2	46.6	5.4	3.8	c	1.39	0.06	5.7	0.33	2.2	18.18
30-60	50.0	42.6	4.3	3.1	c	1.40	0.07	6.2	0.27	2.2	20.79
60-90	52.8	39.9	3.1	4.2	c	1.40	0.10	6.3	0.30	2.2	22.62
90-120	52.6	38.2	4.7	4.5	c	1.42	0.14	6.5	0.18	0.8	21.75
120-150	53.2	38.9	3.7	4.2	c	1.44	0.09	6.4	0.26	1.7	24.79

Table 4(b): Hydraulic characteristics of Typic Tropaquept

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.020	0.616	0.450	0.201	0.249	$1.032 x 10^{-3}$	$1.209 x 10^{-4}$	$5.353 x 10^{-4}$	$5.007 x 10^{-7}$	$6.860 x 10^{-9}$
15-30	0.021	0.622	0.469	0.215	0.195	$5.867 x 10^{-4}$	$6.871 x 10^{-5}$	$3.333 x 10^{-4}$	$3.512 x 10^{-8}$	$4.811 x 10^{-10}$
30-60	0.014	0.632	0.470	0.248	0.179	$2.646 x 10^{-4}$	$3.099 x 10^{-5}$	$3.208 x 10^{-4}$	$5.494 x 10^{-7}$	$7.527 x 10^{-9}$
60-90	0.012	0.655	0.485	0.261	0.192	$1.522 x 10^{-4}$	$1.783 x 10^{-5}$	$2.192 x 10^{-4}$	$1.184 x 10^{-8}$	$1.622 x 10^{-10}$
90-120	0.008	0.647	0.487	0.272	0.216	$1.149 x 10^{-4}$	$1.346 x 10^{-5}$	$6.895 x 10^{-5}$	$5.313 x 10^{-9}$	$7.279 x 10^{-11}$
120-150	0.007	0.668	0.497	0.270	0.200	$1.080 x 10^{-4}$	$1.265 x 10^{-5}$	$1.571 x 10^{-4}$	$5.287 x 10^{-9}$	$7.243 x 10^{-11}$

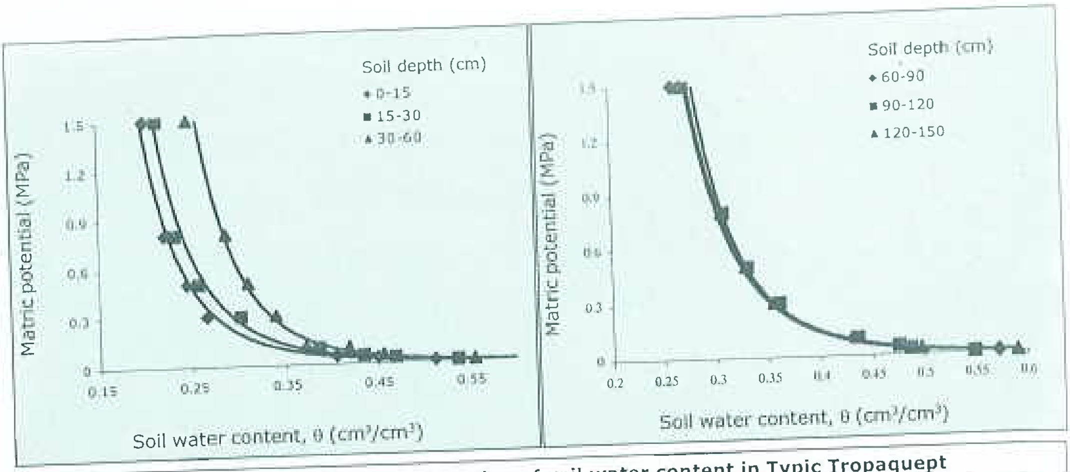

Fig.4a. Matric potential as a funtion of soil water content in Typic Tropaquept

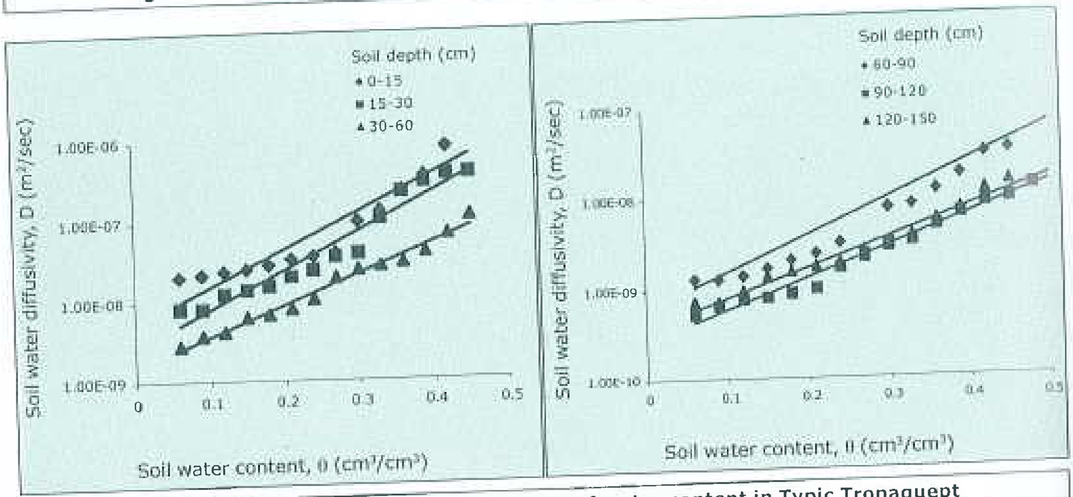

Fig.4b. Soil water diffusivity as a function of water content in Typic Tropaquept

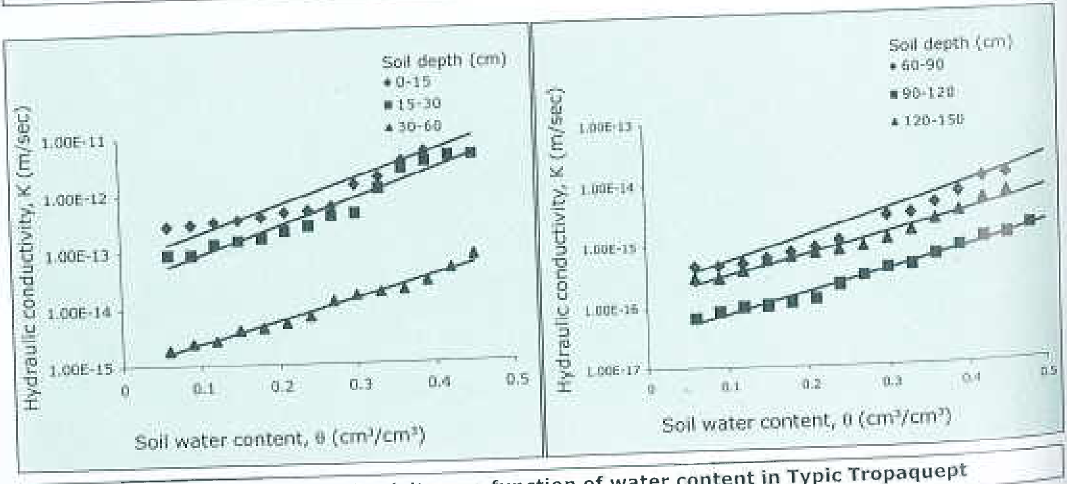

Fig.4c. Hydraulic conductivity as a function of water content in Typic Tropaquept

Table 5 (a): Physicochemical characteristics of Vertic Tropaquept

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC$_2$ (dS/m)	pH$_2$	OC (%)	CaCO$_3$ (%)	CEC (me/100g)
0-15	20.3	15.9	21.6	42.2	scl	1.48	0.19	6.5	0.36	1.1	8.31
15-30	20.2	15.2	23.3	41.3	scl	1.49	0.22	6.6	0.28	0.4	9.61
30-60	24.1	15.7	21.6	38.6	scl	1.50	0.16	6.9	0.19	0.8	8.39
60-90	25.0	18.0	21.9	35.1	scl	1.52	0.19	6.9	0.19	0.4	8.70
90-120	23.4	18.0	19.7	38.9	scl	1.54	0.15	6.9	0.15	0.5	8.35
120-150	27.3	18.2	20.9	33.6	scl	1.55	0.17	6.9	0.15	0.6	9.48

Table 5 (b): Hydraulic characteristics of Vertic Tropaquept

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.091	0.431	0.152	0.071	0.081	1.197×10^{-3}	1.402×10^{-4}	2.520×10^{-4}	8.953×10^{-7}	1.227×10^{-9}
15-30	0.067	0.439	0.158	0.077	0.081	9.467×10^{-4}	1.109×10^{-4}	1.803×10^{-4}	3.141×10^{-7}	4.303×10^{-9}
30-60	0.055	0.443	0.189	0.093	0.096	7.217×10^{-4}	8.453×10^{-5}	3.849×10^{-4}	2.277×10^{-7}	3.119×10^{-9}
60-90	0.051	0.483	0.215	0.105	0.110	3.606×10^{-4}	4.224×10^{-5}	1.361×10^{-4}	6.441×10^{-8}	8.824×10^{-10}
90-120	0.086	0.460	0.208	0.098	0.110	7.485×10^{-4}	8.766×10^{-5}	7.485×10^{-4}	2.576×10^{-7}	3.529×10^{-9}
120-150	0.059	0.500	0.294	0.109	0.185	3.128×10^{-4}	3.663×10^{-5}	1.807×10^{-3}	5.119×10^{-8}	7.013×10^{-10}

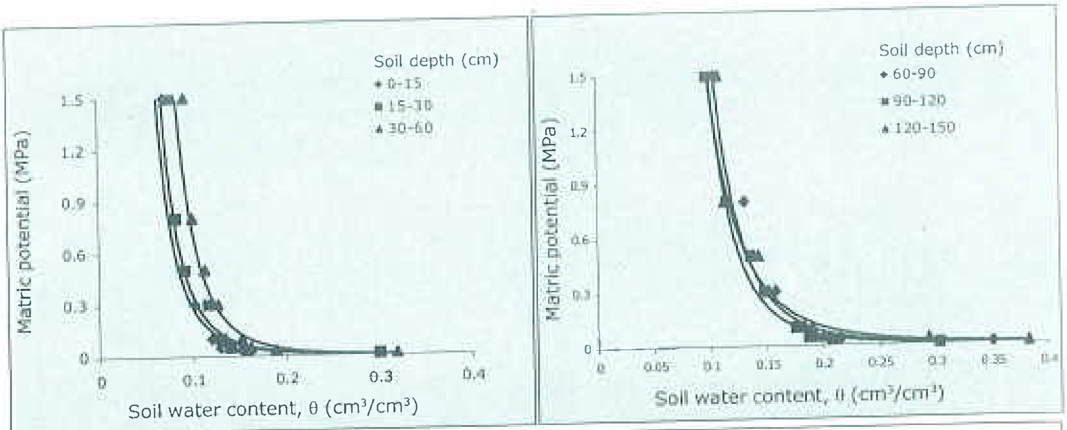

Fig.5a. Matric potential as a funtion of soil water content in Vertic Tropaquept

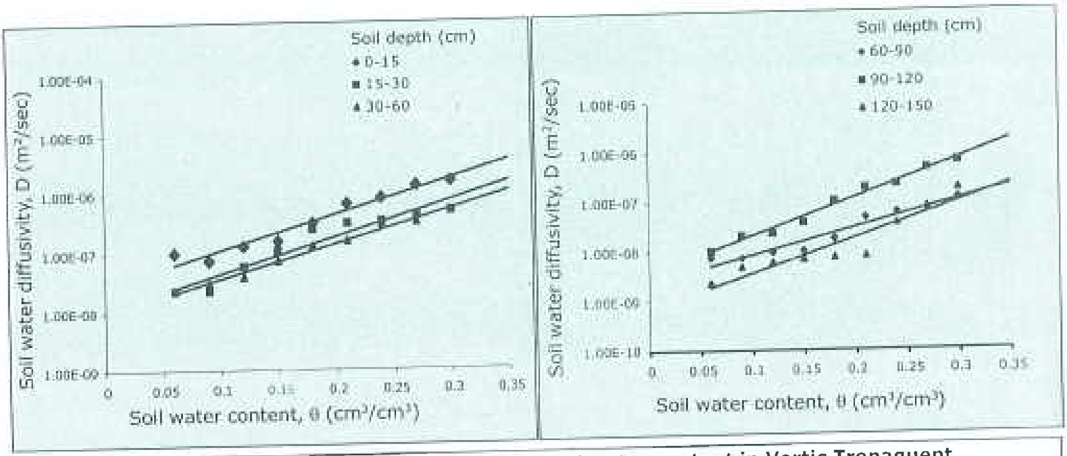

Fig.5b. Soil water diffusivity as a function of water content in Vertic Tropaquept

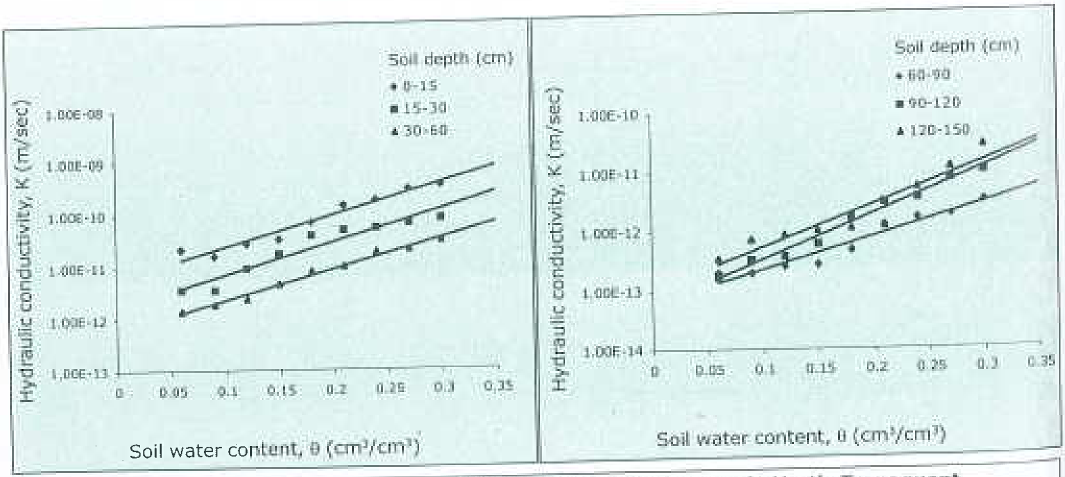

Fig.5c.Hydraulic conductivity as a function of water content in Vertic Tropaquept

Table 6 (a): Physicochemical characteristics of Aeric Tropaquept

Table 6 (a): Physicochemical characteristics of Aeric Tropaquept

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	41.8	43.8	8.7	5.7	c	1.42	0.15	6.0	0.29	0.6	25.51
15-30	45.2	43.9	5.7	5.2	c	1.43	0.24	6.7	0.15	0.8	25.38
30-60	46.7	43.7	5.8	3.8	c	1.44	0.17	6.8	0.09	0.8	27.20
60-90	48.5	42.4	5.5	3.6	c	1.45	0.35	7.6	0.18	1.0	26.46
90-120	47.9	42.7	6.6	2.8	c	1.46	0.32	7.6	0.10	1.2	24.16
120-150	48.0	42.8	5.9	3.3	c	1.48	0.33	7.5	0.11	1.4	25.27

Table 6 (b): Hydraulic characteristics of Aeric Tropaquept

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P ($m/\sqrt{s}$)	Pi ($\sqrt{m}$)	S ($m/\sqrt{s}$)	D (m/s)	Di (m)
0-15	0.023	0.604	0.449	0.169	0.280	1.257×10^{-3}	1.472×10^{-4}	5.712×10^{-4}	5.750×10^{-7}	7.00×10^{-9}
15-30	0.027	0.605	0.415	0.208	0.207	6.008×10^{-4}	7.037×10^{-5}	2.403×10^{-4}	1.810×10^{-7}	2.00×10^{-9}
30-60	0.020	0.608	0.435	0.198	0.237	2.929×10^{-4}	3.431×10^{-5}	1.601×10^{-4}	3.20×10^{-8}	4.468×10^{-10}
60-90	0.011	0.633	0.461	0.215	0.246	2.841×10^{-4}	3.327×10^{-5}	1.490×10^{-4}	3.10×10^{-8}	4.363×10^{-10}
90-120	0.010	0.598	0.448	0.206	0.242	3.723×10^{-4}	4.361×10^{-5}	1.715×10^{-4}	5.500×10^{-8}	7.617×10^{-10}
120-150	0.010	0.611	0.451	0.201	0.250	3.747×10^{-4}	4.516×10^{-5}	1.652×10^{-4}	5.151^{-8}	6.107×10^{-10}

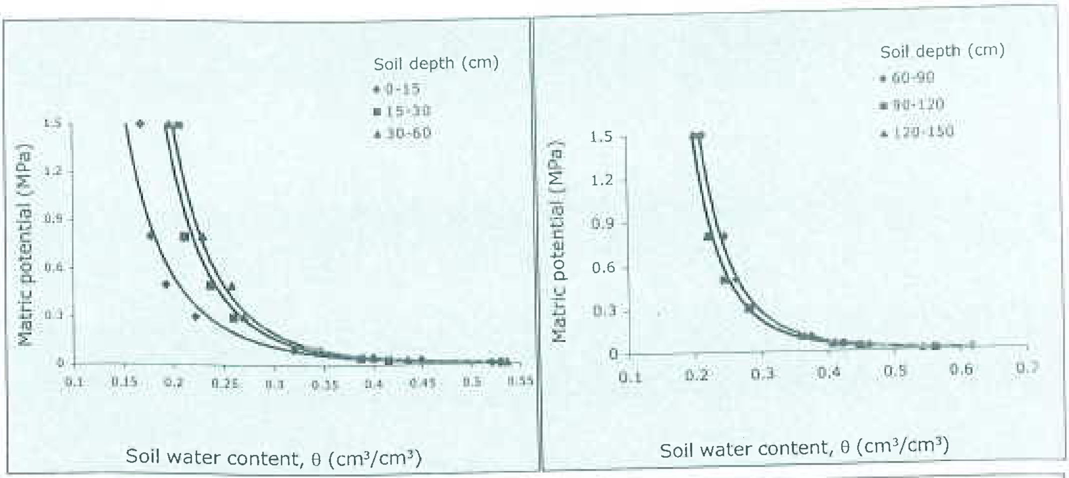

Fig. 6a. Matric potential as a funtion of soil water content in Aeric Tropaquept

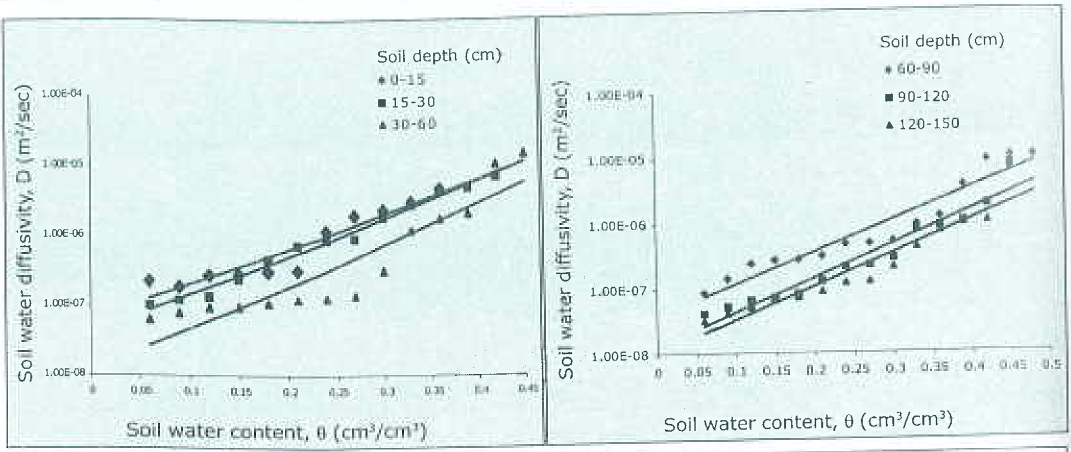

Fig.6b. Soil water diffusivity as a function of water content in Aeric Tropaquept

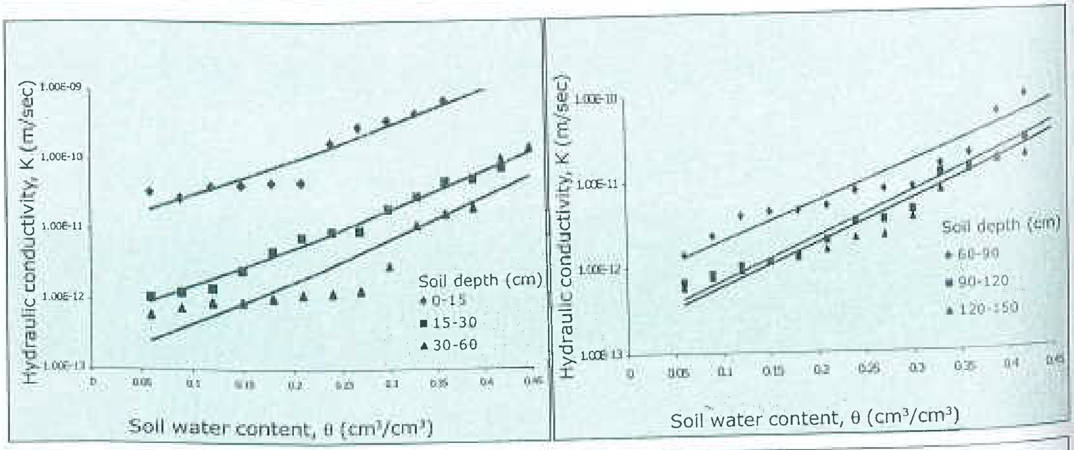

Fig.6c. Hydraulic conductivity as a function of water content in Aeric Tropaquept

Table 7 (a): Physicochemical characteristics of Typic Ustochrept

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC$_2$ (dS/m)	pH$_2$	OC (%)	CaCO$_3$ (%)	CEC (me/100g)
0-15	50.7	30.9	9.7	6.7	c	1.38	0.22	6.8	0.50	1.8	32.13
15-30	51.8	32.8	8.7	6.7	c	1.39	0.18	7.5	0.72	2.0	39.22
30-60	58.7	26.8	7.2	7.3	c	1.40	0.63	7.4	0.26	2.2	43.10
60-90	62.8	28.9	4.4	3.8	c	1.41	0.34	7.7	0.23	2.2	46.26
90-120	50.5	33.4	6.8	9.3	c	1.42	0.60	7.5	0.25	2.3	43.20
120-150	52.7	32.3	7.2	7.8	c	1.42	0.60	7.4	0.25	2.3	42.30

Table 7 (b): Hydraulic characteristics of Typic Ustochrept

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/$\sqrt{s}$)	Pi ($\sqrt{m}$)	S (m/$\sqrt{s}$)	D (m/s)	Di (m)
0-15	0.027	0.675	0.516	0.238	0.278	4.637×10^{-4}	5.432×10^{-5}	2.233×10^{-4}	1.250×10^{-7}	1.00×10^{-9}
15-30	0.019	0.669	0.525	0.242	0.283	7.214×10^{-4}	8.449×10^{-5}	3.160×10^{-4}	2.930×10^{-7}	4.00×10^{-9}
30-60	0.021	0.638	0.559	0.255	0.304	2.263×10^{-4}	2.650×10^{-5}	1.075×10^{-4}	3.100×10^{-8}	4.337×10^{-10}
60-90	0.020	0.674	0.609	0.286	0.323	3.468×10^{-4}	4.062×10^{-5}	1.434×10^{-4}	5.600×10^{-8}	7.814×10^{-10}
90-120	0.016	0.664	0.570	0.265	0.305	3.699×10^{-4}	4.332×10^{-5}	1.837×10^{-4}	9.200×10^{-8}	1.00×10^{-9}
120-150	0.016	0.657	0.565	0.271	0.294	3.541×10^{-4}	4.215×10^{-5}	1.673×10^{-4}	7.761×10^{-8}	9.467×10^{-10}

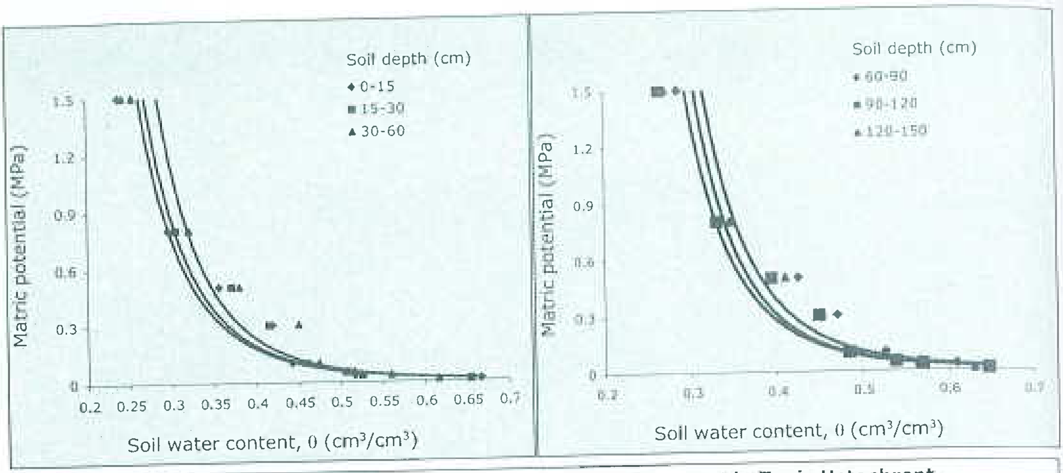

Fig.7a. Matric potential as a funtion of soil water content in Typic Ustochrept

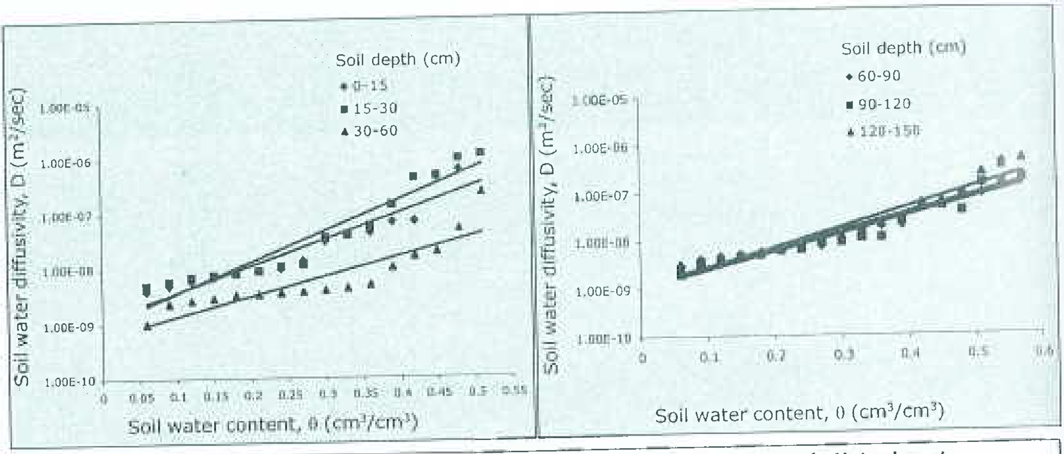

Fig.7b. Soil water diffusivity as a function of water content in Typic Ustochrept

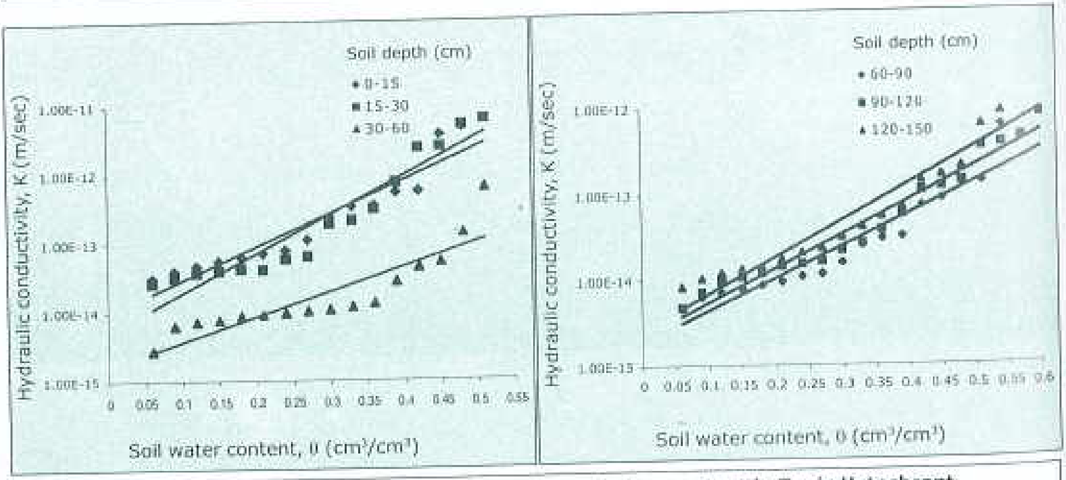

Fig. 7c. Hydraulic conductivity as a function of water content in Typic Ustochrept

Table 8 (a): Physicochemical characteristics of Vertic Ustochrept

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	16.5	13.5	24.2	45.8	sl	1.47	0.07	5.3	0.51	0.3	7.48
15-30	27.6	13.6	24.3	34.5	scl	1.50	0.22	6.4	0.12	0.4	11.57
30-60	32.6	13.2	16.2	38.0	scl	1.48	0.26	6.9	0.09	0.6	13.05
60-90	34.0	13.0	15.2	37.8	scl	1.48	0.43	7.1	0.06	0.9	13.92
90-120	36.0	12.8	16.8	34.4	sc	1.49	0.36	7.3	0.03	1.0	13.05
120-150	35.6	13.4	15.3	35.7	sc	1.50	0.22	7.1	0.06	1.6	12.18

Table 8(b): Hydraulic characteristics of Vertic Ustochrept

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/$\sqrt{s}$)	Pi ($\sqrt{m}$)	S (m/$\sqrt{s}$)	D (m/s)	Di (m)
0-15	0.102	0.440	0.210	0.070	0.140	1.642×10^{-3}	1.902×10^{-4}	5.052×10^{-4}	7.962×10^{-7}	1.091×10^{-8}
15-30	0.042	0.565	0.312	0.128	0.184	3.257×10^{-4}	3.815×10^{-5}	1.265×10^{-4}	3.879×10^{-8}	5.314×10^{-10}
30-60	0.018	0.520	0.337	0.147	0.190	2.014×10^{-4}	2.358×10^{-5}	6.712×10^{-5}	1.329×10^{-8}	1.821×10^{-10}
60-90	0.015	0.608	0.370	0.185	0.185	2.041×10^{-4}	2.391×10^{-5}	2.041×10^{-4}	1.878×10^{-8}	2.573×10^{-10}
90-120	0.014	0.628	0.377	0.196	0.181	2.041×10^{-4}	2.391×10^{-5}	1.225×10^{-4}	1.750×10^{-8}	2.398×10^{-10}
120-150	0.014	0.611	0.371	0.190	0.181	1.390×10^{-4}	1.628×10^{-5}	7.646×10^{-5}	5.146×10^{-9}	7.050×10^{-11}

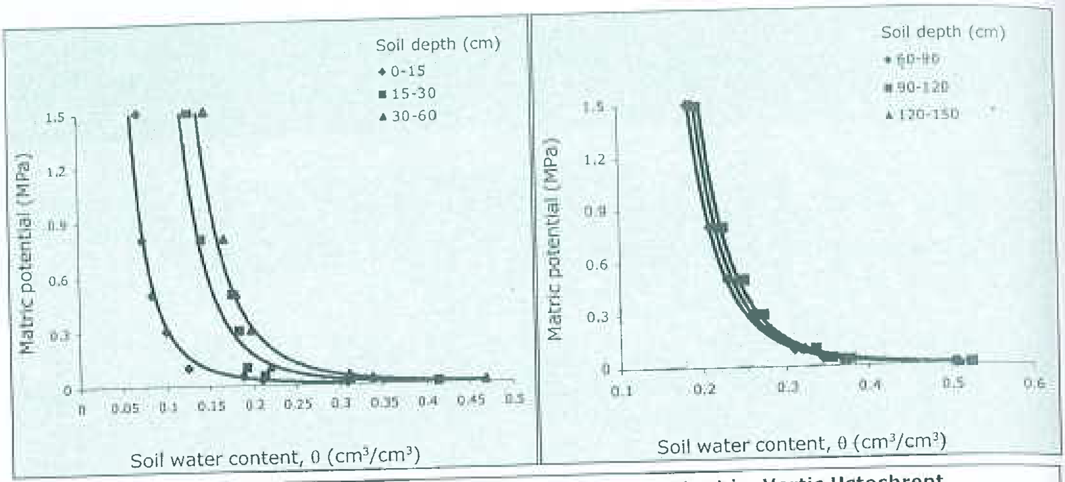

Fig.8a. Matric potential as a funtion of soil water content in Vertic Ustochrept

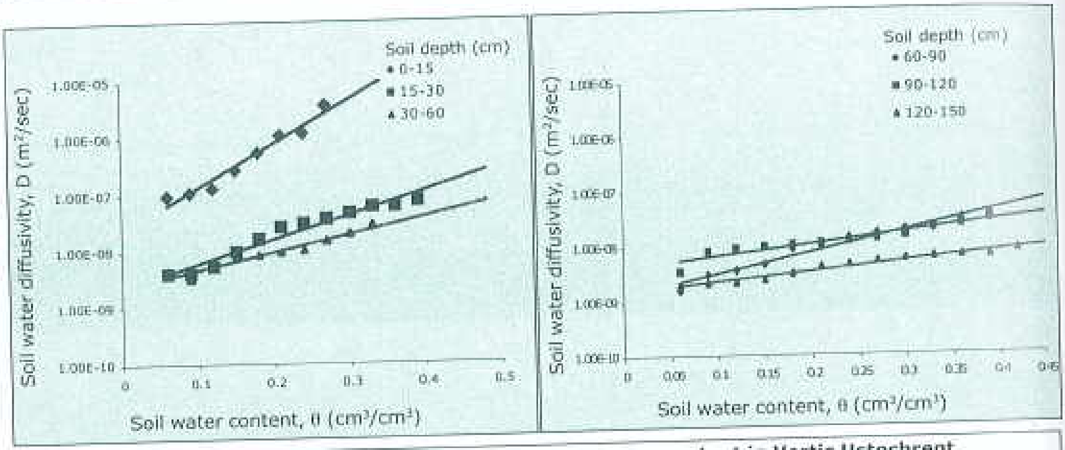

Fig.8b. Soil water diffusivity as a function of water content in Vertic Ustochrept

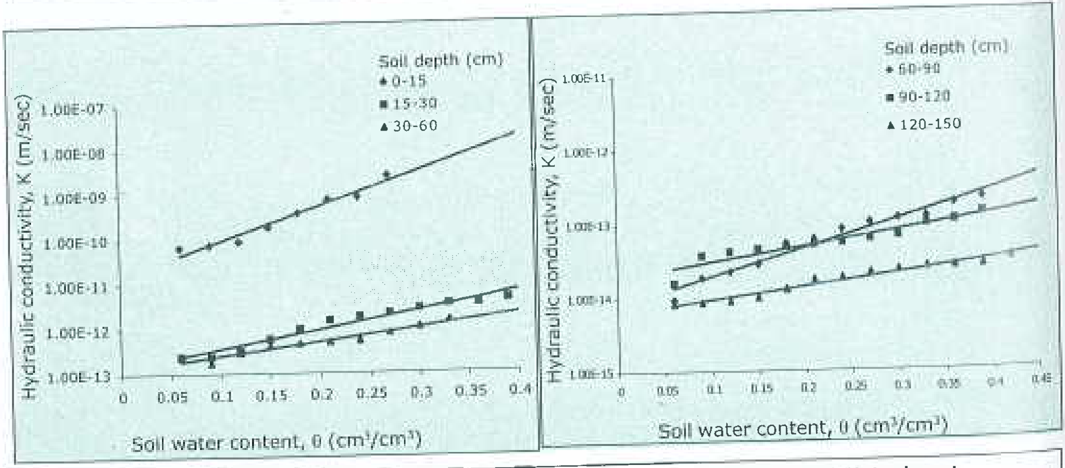

Fig.8c. Hydraulic conductivity as a function of water content in Vertic Ustochrept

Table 9 (a): Physicochemical characteristics of Typic Ustropept

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	28.5	22.5	34.4	14.6	scl	1.44	0.20	6.7	0.60	0.7	12.18
15-30	33.7	20.6	33.1	12.6	scl	1.44	0.12	6.8	0.37	1.0	18.44
30-60	37.5	22.7	28.6	11.2	cl	1.45	0.12	6.9	0.21	0.6	23.92
60-90	40.4	26.8	24.5	8.3	c	1.46	0.20	6.9	0.28	0.5	26.97
90-120	40.0	25.4	22.3	12.3	c	1.46	0.24	7.1	0.24	0.2	22.18
120-150	40.0	24.9	23.0	12.1	c	1.48	0.23	7.2	0.19	1.2	24.36

Table 9 (b): Hydraulic characteristics of Typic Ustropept

Soil depth (cm)	Ks (cm/hr)	θs (cm³/cm³)	θ (cm³/cm³) at 0.033 MPa	θ(cm³/cm³) at 1.5 MPa	Available water content (cm³/cm³)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.900	0.571	0.328	0.136	0.192	1.921×10^{-3}	2.249×10^{-4}	1.854×10^{-3}	2.270×10^{-6}	3.110×10^{-8}
15-30	0.742	0.609	0.360	0.141	0.219	1.404×10^{-3}	1.644×10^{-4}	7.947×10^{-4}	8.712×10^{-7}	1.194×10^{-8}
30-60	0.446	0.623	0.396	0.169	0.227	7.007×10^{-4}	8.206×10^{-5}	7.785×10^{-4}	2.777×10^{-7}	3.805×10^{-9}
60-90	0.012	0.609	0.432	0.190	0.242	6.183×10^{-4}	7.242×10^{-5}	9.456×10^{-4}	1.441×10^{-7}	1.974×10^{-9}
90-120	0.011	0.619	0.420	0.192	0.228	3.269×10^{-4}	3.828×10^{-5}	7.191×10^{-4}	5.572×10^{-8}	7.634×10^{-10}
120-150	0.011	0.632	0.429	0.198	0.231	5.298×10^{-4}	6.205×10^{-5}	1.987×10^{-4}	8.098×10^{-8}	1.109×10^{-9}

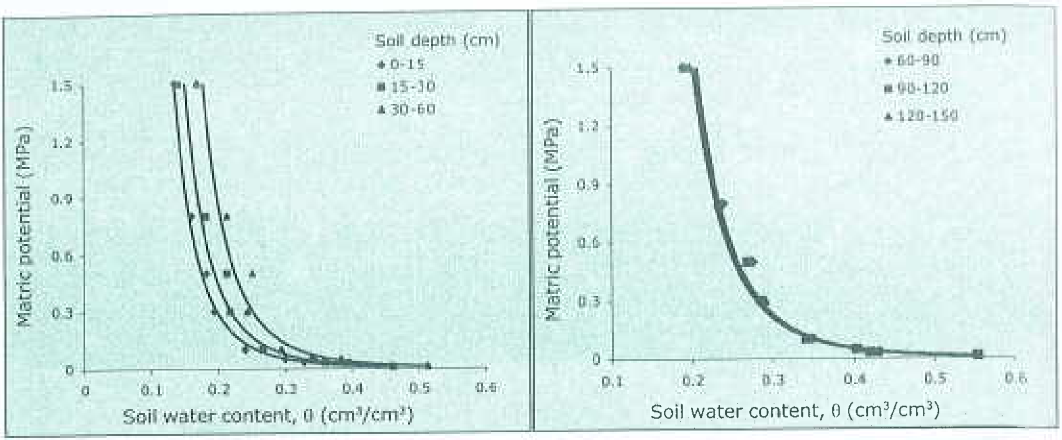

Fig.9a. Matric potential as a funtion of soil water content in Typic Ustropept

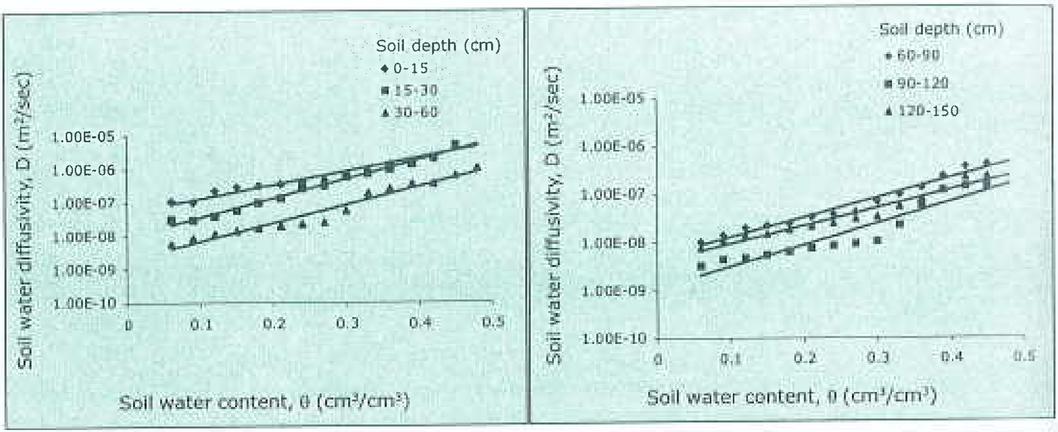

Fig.9b. Soil water diffusivity as a function of water content in Typic Ustropept

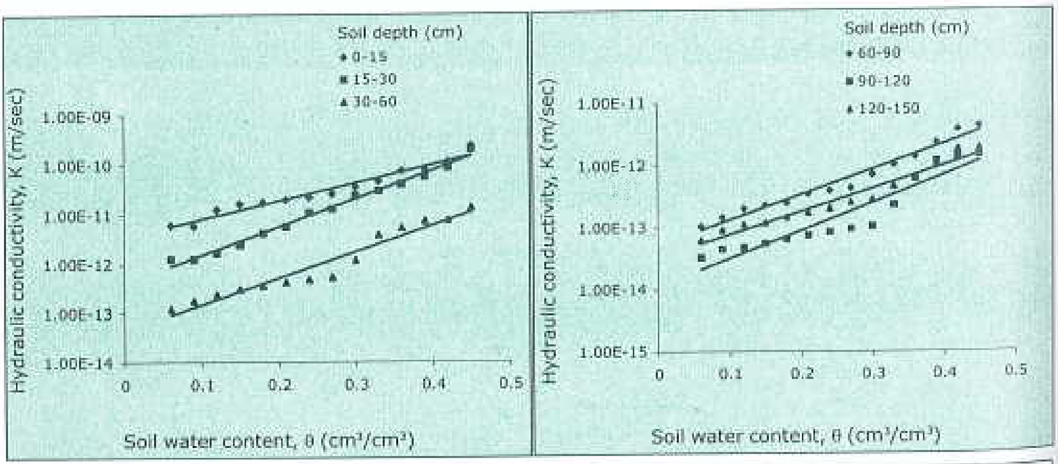

Fig. 9c. Hydraulic conductivity as a function of water content in Typic Ustropept

10: Water storage capacity of the inceptisol profiles

Name of the subgroup	Profile water storage capacity (cm/m depth)	Category for profile water capacity
Aeric Tropaquept	22.87	Very high
Aeric Haplaquept	20.25	Very high
Typic Ustochrept	30.28	Very high
Vertic Haplaquept	24.04	Very high
Vertic Tropaquept	9.71	Low
Typic Ustropept	22.52	Very high
Typic Tropaquept	23.08	Very high
Vertic Ustocrept	17.92	High

Table 11: Erosion Index of the inceptisol profiles

Soil subgroup	Erosion index			
	Soil depth (cm)			Mean
	0- 15	15 -30	30 –150	
Aeric Tropaquept	22.01	20.26	24.19	22.15
Aeric Haplaquept	39.16	28.38	26.51	29.35
Typic Ustochrept	17.86	20.13	19.48	19.16
Vertic Haplaquept	15.41	16.52	13.66	15.20
Vertic Tropaquept	36.81	30.97	30.72	32.83
Typic Ustropept	23.55	22.65	16.10	20.77
Typic Tropaquept	15.66	15.46	16.96	16.03
Vertic Ustochrept	41.62	35.08	38.86	38.52
Mean	26.51	23.68	23.31	
C D (P=0.05) to compare	soil subgroup means:		1.11	
	soil depth means:		0.68	
	subgroup x depth:		0.51	

Tropaquept. The lowest available water content was found in Vertic Tropaquept. In surface layer, the highest saturated hydraulic conductivity, Ks, (0.9 cm/hr) was observed in Typic Ustropept followed by Aeric Haplaquept (0.146 cm/hr) and Vertic Ustochrept (0.102 cm/hr). The lowest saturated hydraulic conductivity (0.020 cm/hr) was observed in Typic Tropaquept; in other subgroups, it varied from 0.023 to 0.091 cm/hr.

Data on penetrability (P), intrinsic penetrability (Pi), sorptivity (S), weighted mean diffusivity (D) and intrinsic weighted mean diffusivity (Di) of water in the soil are presented in Tables 2b to 9b. Penetrability and intrinsic penetrability in the soils followed similar pattern. Penetrability values were found to be the highest in Aeric Haplaquept and the lowest in Typic Ustochrept. The sorptivity was highest in Typic Ustropept (1.854×10^{-3} m/√s) followed by Vertic Haplaquept (7.229×10^{-4} m/√s) and Aeric Tropaquept (5.712×10^{-4} m/√s). The lowest sorptivity (2.233×10^{-4} m/√s) was found in Typic Ustrochept. The Lowest weighted mean diffusitivity (1.25×10^{-7}m/s) as well as intrinsic weighted mean diffusivity (1.00×10^{-9} m) were found in Typic Ustochrept. While Typic Ustropept had the highest weighted mean diffusivity (2.270×10^{-6} m/s) as well as intrinsic mean diffusivity (3.11×10^{-8} m).

Data on water diffusivity and hydraulic conductivity in the soils as function of water content are presented in Fig. 2b to 9b and 2c to 9c, respectively. Both the parameters varied widely with soil type. In general, values of water diffusivity and conductivity were lower in fine textured than in coarse textured soils. In all the soils, unsaturated hydraulic conductivity $K(\theta)$ and water diffusivity, $D(\theta)$, decreased with decrease in their water content. Magnitude of the change in $K(\theta)$ and $D(\theta)$ with water content, θ, also varied with soil type.

4.1.2 Profile water storage capacity:

Profile water storage capacity per metre depth, calculated from soil water retention data for Inceptisols are presented in Table 10. Out of 8 soil subgroups, 1 was with low, 1 with high and 6 with very high water storage capacity. Very high profile water storage capacity was observed in Aeric Tropaquept, Aeric Haplaquept, Typic Ustochrept, Vertic Haplaquept, Typic Ustropept and Typic Tropaquept. The storage capacity was high in Vertic Ustochrept and low in Vertic Tropaquept.

4.1.3 Erosion Index:

Mean EI values for Inceptisols are presented in Table 11. In 0-15 cm soil depth, the highest EI of 41.62 was observed in Vertic Ustochrept followed by Aeric Haplaquept (39.16) and Vertic Tropaquept (36.81). The lowest EI of 15.41 was observed in Vertic Haplaquept. No significant difference was observed between Vertic Haplaquept and Typic Tropaquept. In 15-30 cm soil depth, the highest EI value of 35.08 was observed in Vertic Ustochrept and the lowest of 15.46 in Typic Tropaquept. No significant difference was observed between Aeric Tropaquept and Typic Ustochrept, and between Vertic Haplaquept and Typic Tropaquept. In 30-150 cm soil depth, the highest EI of 38.86 was observed in Vertic Ustochrept and the lowest EI of 13.66 was observed in Vertic Haplaquept. No significant diference was observed between Typic Ustropept and Typic Tropaquept. Mean EI value was significantly higher for soil at 0-15 cm than that at 15-30 and 30-150 cm depths.

4.1.4 Water management implications

The ψ- θ relationships, soil water conductivity and diffusivity of soils suggest that frequent irrigations using small amont of water each time will be required to improve use efficiency of water applied to Vertic Tropaquept, Vertic Ustochrept, Typic Ustropept and Aeric Haplaquept. Drip or sprinkler irrigation will prove useful to improve use efficiency of applied water and increase crop yield in these subgroups. Application of medium to heavy irrigation at long intervals, however, may be practised in Aeric Tropaquept, Typic Tropaquept, Vertic Haplaquept and Typic Ustochrept for higher water use efficiency without any adverse effect.

Data on Penetrability, intrinsic penetrability and sorptivity reveal that adoption of suitable management practices for *in situ* conservation of water will be necessary to improve water use efficiency in Typic Ustochrept, Vertic Haplaquept, Typic Tropaquept and in Vertic Tropaquept. Application of organic materials like green manure, FYM and green manure with lime will prove very effective for improving water use efficiency in Aeric Tropaquept, Vertic Tropaquept, Vertic Ustochrept and Aeric Haplaquept.

In Aeric Tropaquept, Aeric Haplaquept, Typic Ustochrept, Vertic Haplaquept, Typic Ustropept and Typic Tropaquept, cultivation of a second crop without irrigation is possible after rainy season provided it is sown immediately after the harvest of *kharif* crop. In Vertic Ustochrept subgroup, a second crop without irrigation is possible either as a *paira* crop or with mulching. In Vertic Tropaquept, second crop is not possible without irrigation facilities. All the soil subgroups need adoption of appropriate soil and water conservation techniques.

4.2 Soil Order: ALFISOL

Alfisols are base-rich mineral soils characterised by a light-coloured surface horizon over a clay enriched argillic subsurface horizon. They are rich in Fe, Al oxides with base saturation of more than 35 per cent. Alfisols are more strongly weathered than the Inceptisols, but less so than the Ultisols. Thin to thick clay coatings (cutons) are observed on the bed faces in their B-horizons. These soils tend to develop under varied types of climate and vegetation. The removal of flocculating agents, like Ca-Mg carbonates and bicarbonates, is a prerequisite for the movement of clay under the influence of percolating water. In Orissa, Alfisols have been subdivided into two sub orders, viz. Aqualf and Ustalf. The Aqualfs are the Alfisols which remain seasonally saturated with water and Ustalfs are the Alfisols of semi-arid to sub-humid climatic conditions representing ustic soil moisture regime. They are developed in areas with summer monsoon rains and that have epipedons which are both massive and hard or very hard when dry.

There are 3 great groups under the suborder Ustalf, viz., Haplustalf, Paleustalf and Rhodustalf, and one great group under Aqualf, viz., Ochraqualf.

Haplustalfs: Haplustalfs are relatively thin, reddish to brownish red but not dark red soils. They have gradual or clear (not abrupt) upper boundary of the argillic horizon. These Ustalfs are on relatively recent erosional surfaces or deposits.

Paleustalfs: Paleustalfs are the thick redish or red Ustalfs that are on old surfaces. Many of them have some plinthite in their lower horizons. They occur on relatively stable landscape positions, their slopes are gentle, and their genesis began before the late Pleistocene.

Rhodustalfs: Rhodustalfs are dark red Ustalfs that have a thiner solum than the Paleustalfs. Mostly they are on erosional surfaces. They have an argillic horizon throughout its thickness and has a colour hue redder than 5 YR.

Ochraqualfs: Ochraqualfs are the Aqualfs of midlatitudes that have an ochric epipedon resting on an argillic horizon without an abrupt textural change. Ground water fluctuates below the argillic horizon. They, generally, are nearly level and their parent materials are late- pleistocene sediments. They have 60 per cent or more of the matrix in all sub-horizons between the Al or Ap horizon and a depth of 75 cm, mottled colour with chroma, moist of 2 or less and the hue is 2.5 Y. For subgroups, typic is used to define the central concept of a great group. If some deviation is noticed from the central theme, depending on the intergradations, other words are used. In Orissa, 8 dominating subgroups under this order are found. They are:

1. Typic Haplustalf
2. Typic Paleustalf
3. Ultic Paleustalf
4. Kandic Paleustalf
5. Rhodic Paleustalf

6. Typic Rhodustalf
7. Typic Ochraqualf
8. Aeric Ochraqualf

4.2.1 Physicochemical and hydrological characteristics:

Physicochemical and hydrological characteristics of the Alfisol profiles are presented in Tables 12 to 19. Texture of the soil ranged from sandy loam to clay, with clay content varying from 17.3 to 56 per cent. Highest clay content was observed in Typic Paleustalf (56%) followed by Kandic Paleustalf (53%) and Rhodic Paleustalf (45.7%). Lowest clay content was observed in Ultic Paleustalf. Clay content in the soils generally increased with depth indicating movement of clay from surface to sub-surface layers. Bulk density in the soils generally increased with depth. The highest bulk density was observed in Ultic Paleustalf, where it varied from 1.51 to 1.54 Mgm^{-3}. In other subgroups, in 0-15 cm soil layer, it ranged from 1.39 to 1.51 Mgm^{-3}. The lowest bulk density was observed in Rhodic Paleustalf, where it varied from 1.39 to 1.46 Mgm^{-3}.

Organic carbon (OC) content in the soils generally decreased with depth. Highest OC content was observed in Typic Haplustalf, where it varied from 0.21 to 0.60% and the lowest OC was observed in Rhodic Paleustalf. In 0-15 cm layers, OC ranged from 0.234 to 0.6%. In general, pH$_2$ increased as the soil depth increased. In 0-15 cm soil layer, pH$_2$ ranged from 5.2 to 6.98 and in 120-150 cm soil layer, pH$_2$ ranged from 6.2 to 7.3. Data on electrical conductivity showed that all soils were free from salinity problem. In 0 -15 cm soil layer, EC$_2$ varied from 0.03 to 0.85 dS/m. All the soil sub-groups were non calcareous in nature and their CaCO$_3$ content varied from 0.3 to 2.3%. Cation exchange capacity of the soil varied widely depending upon texture of the soil or clay content. The highest CEC was observed in Typic Ochraqualf and the lowest in Ultic Paleustalf. In all other subgroups, it varied from 6.1 to 24.1 me/100 g.

Saturated hydraulic conductivity (Ks), water content at saturation, 0.033 and 1.5 MPa, and available water content are presented in Tables 12b to 19b. The highest saturated hydraulic conductivity was observed in Ultic

Paleustalf, where it ranged from 0.987 to 1.478 cm/hr followed by Rhodic Paleustalf (1.047 cm/hr), Ultic Paleustalf (0.9878 cm/hr) and Typic Paleustalf (0.812 cm/hr). The lowest saturated hydraulic conductivity was observed in Typic Ochraqualf (0.065 cm/hr). Soil water retention characteristics (Ψ-θ relationships) are presented in Fig. 10a to17a. At 0.033 MPa, highest water was retained by Typic Ocharaqualf, where it ranged from 0.379 to 0.453 cm^3cm^{-3} followed by Typic Haplustalf and Aeric Ochraqualf. Water retention was the lowest in Ultic Paleustalf, where it varied from 0.170 to 0.259 cm^3 cm^{-3}. Similar trends of water retention by the soils were recorded for 1.5 MPa. The highest available water content was found in Typic Haplustalf followed by Aeric Ochraqualf and Typic Ochraqualf. The lowest available water content 0.110-0.1124 cm^3 cm^{-3} was observed in Ultic Paleustalf.

Penetrability (P), intrinsic penetrability (Pi), sorptivity (s), weighted mean diffusivity (D) and intrinsic weighted mean diffusivity (Di) of water in the soil are presented in Tables 12b to19b. Highest penetrability and intrinsic penetrability values were found in Typic Paleustalf and the lowest in Typic Ochraqualf. The highest value of sorptivity was observed in Typic Paleustalf followed by Rhodic Paleustalf and Ultic Paleustalf. The lowest sorptivity (3.676×10^{-5} m/$\sqrt{s}$) was found in Typic Ochraqualf. The highest weighted mean diffusivity (4.929×10^{-6} m/s) as well as intrinsic weighted mean diffusivity (6.7×10^{-8} m) were found in Typic Paleustalf. While weighted mean diffusivity was the lowest in Typic Ochraqualf (2.970×10^{-8} m/s), the lowest intrinsic mean diffusivity was found in Typic Ochraqualf (4.069×10^{-10} m).

Soil water diffusivity and hydraulic conductivity as a function of water content are presented in Fig 10b to 17b and Fig 10c to 17c, respectively. In all the subgroups, unsaturated hydraulic conductivity and soil water diffusivity decreased with their water content. Magnitude of change in $K(\theta)$ and $D(\theta)$ was high in coarse textured than in fine textured soils.

4.2.2 Profile water storage capacity:

Profile water storage capacity of Alfisols are presented in Table 20. Out of 8 soil subgroups, 3 were with medium, 3 with high and 2 with very high

Table 12 (a): Physico chemical characteristics of Typic Haplustalf

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	Ca CO_3 (%)	CEC (me/100g)
0-15	33.8	31.0	18.2	17.0	cl	1.43	0.07	5.9	0.60	1.5	15.92
15-30	33.0	30.4	18.3	18.3	cl	1.43	0.04	6.1	0.44	0.7	16.44
30-60	30.3	26.1	19.6	24.0	cl	1.44	0.03	6.3	0.29	0.9	14.44
60-90	33.2	25.3	19.7	21.8	cl	1.45	0.04	6.6	0.29	1.2	15.22
90-120	32.4	23.1	18.9	25.6	scl	1.47	0.04	6.7	0.20	1.7	14.44
120-150	31.2	22.0	14.0	32.8	scl	1.48	0.03	6.9	0.21	1.7	13.57

Table 12 (b): Hydraulic characteristics of Typic Haplustalf

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/$\sqrt{s}$)	Pi ($\sqrt{m}$)	S (m/$\sqrt{s}$)	D (m/s)	Di (m)
0-15	0.124	0.603	0.442	0.179	0.263	8.704×10^{-4}	1.019×10^{-4}	9.139×10^{-4}	3.340×10^{-7}	4.576×10^{-9}
15-30	0.114	0.593	0.430	0.175	0.255	9.297×10^{-4}	1.089×10^{-4}	4.447×10^{-4}	2.553×10^{-7}	3.498×10^{-9}
30-60	0.103	0.544	0.369	0.159	0.210	6.811×10^{-4}	7.978×10^{-5}	2.085×10^{-4}	1.780×10^{-7}	2.439×10^{-9}
60-90	0.100	0.568	0.405	0.182	0.223	6.260×10^{-4}	7.332×10^{-5}	3.402×10^{-4}	1.865×10^{-7}	2.555×10^{-9}
90-120	0.097	0.548	0.385	0.183	0.202	7.742×10^{-4}	9.068×10^{-5}	3.758×10^{-4}	3.410×10^{-7}	4.672×10^{-9}
120-150	0.074	0.537	0.365	0.170	0.195	9.176×10^{-4}	1.075×10^{-4}	7.647×10^{-4}	3.358×10^{-7}	4.601×10^{-9}

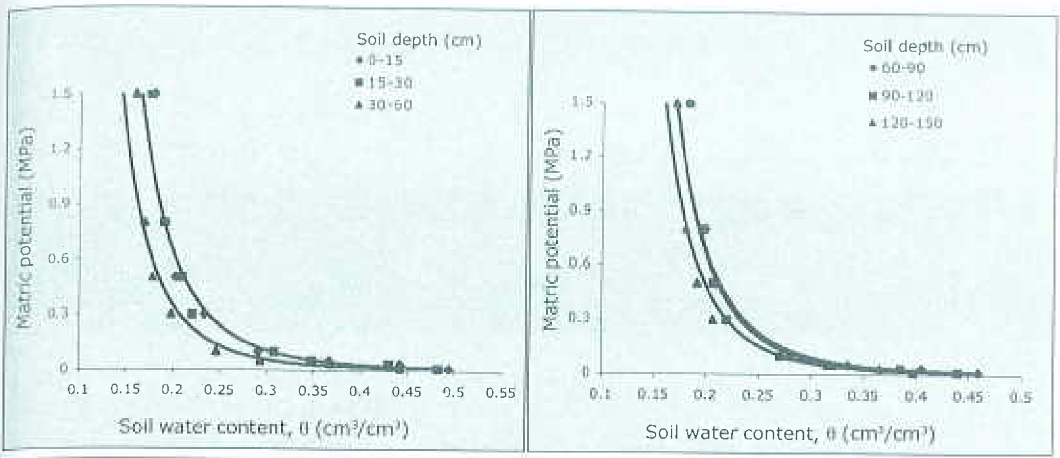

Fig.10a. Matric potential as a funtion of soil water content in Typic Haplustalf

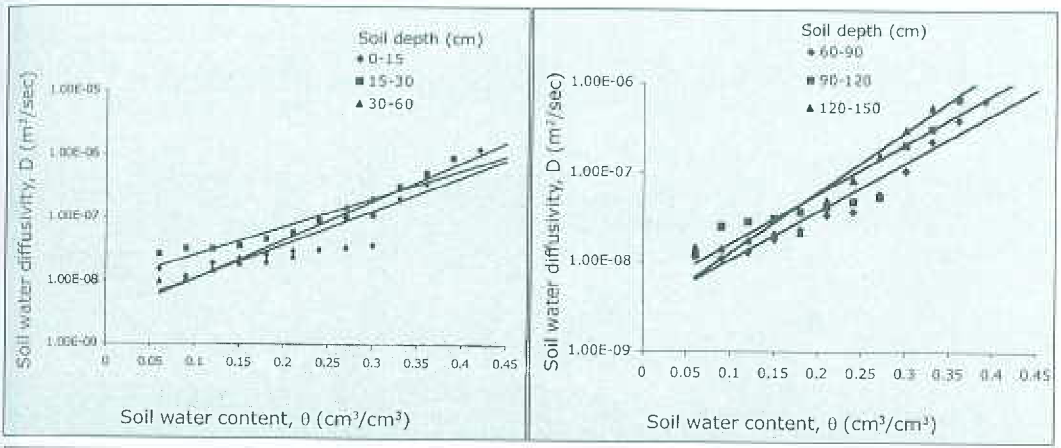

Fig.10b. Soil water diffusivity as a function of water content in Typic Haplustalf

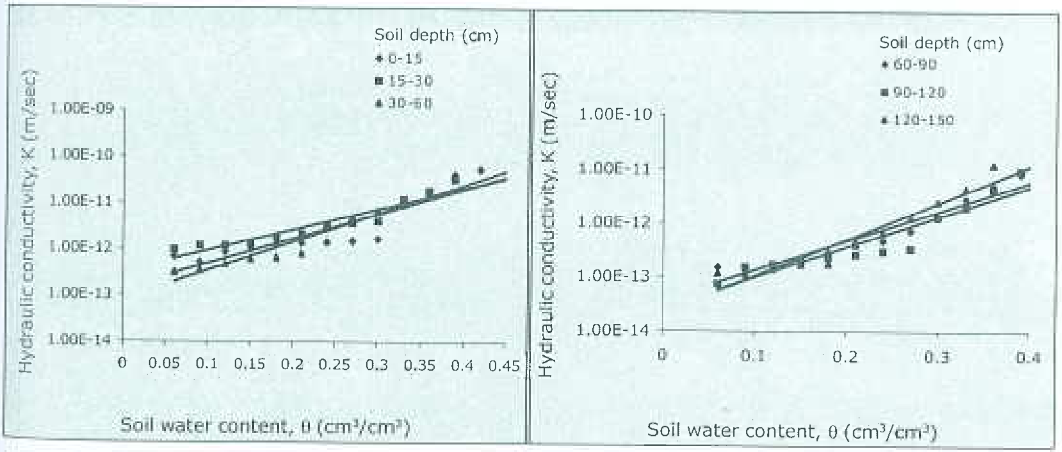

Fig.10c. Hydraulic conductivity as a function of water content in Typic Haplustalf

Table 13 (a): Physico chemical characteristics of Typic Paleustalf

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	28.2	15.3	24.0	32.5	scl	1.46	0.08	5.8	0.51	0.4	9.35
15-30	55.9	12.3	13.0	18.8	c	1.48	0.08	6.1	0.21	0.3	10.03
30-60	45.3	14.2	14.7	25.8	c	1.49	0.09	5.9	0.31	0.6	10.10
60-90	50.6	15.1	15.4	18.9	c	1.51	0.07	6.2	0.26	0.6	13.16
90-120	53.6	15.2	15.3	15.9	c	1.52	0.09	6.1	0.25	0.8	13.16
120-150	52.2	15.9	15.0	16.9	c	1.52	0.08	6.0	0.25	1.0	13.20

Table 13 (b): Hydraulic characteristics of Typic Paleustalf

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/$\sqrt{s}$)	Pi ($\sqrt{m}$)	S (m/$\sqrt{s}$)	D (m/s)	Di (m)
0-15	0.812	0.513	0.298	0.134	0.164	$2.566x10^{-3}$	$2.994x10^{-4}$	$1.084x10^{-3}$	$3.043x10^{-6}$	$4.100x10^{-8}$
15-30	0.672	0.536	0.330	0.181	0.149	$2.251x10^{-3}$	$2.519x10^{-4}$	$7.713x10^{-4}$	$4.929x10^{-6}$	$6.700x10^{-8}$
30-60	1.712	0.564	0.365	0.205	0.160	$2.510x10^{-3}$	$2.940x10^{-4}$	$1.037x10^{-3}$	$4.906x10^{-6}$	$6.700x10^{-8}$
60-90	1.152	0.584	0.395	0.229	0.166	$2.319x10^{-3}$	$2.716x10^{-4}$	$1.064x10^{-3}$	$2.039x10^{-6}$	$2.700x10^{-8}$
90-120	1.892	0.576	0.376	0.206	0.170	$2.514x10^{-3}$	$2.944x10^{-4}$	$1.006x10^{-3}$	$3.766x10^{-6}$	$5.100x10^{-8}$
120-150	0.601	0.561	0.381	0.212	0.169	$2.413x10^{-3}$	$2.814x10^{-4}$	$1.107x10^{-3}$	$3.016x10^{-6}$	$5.019x10^{-8}$

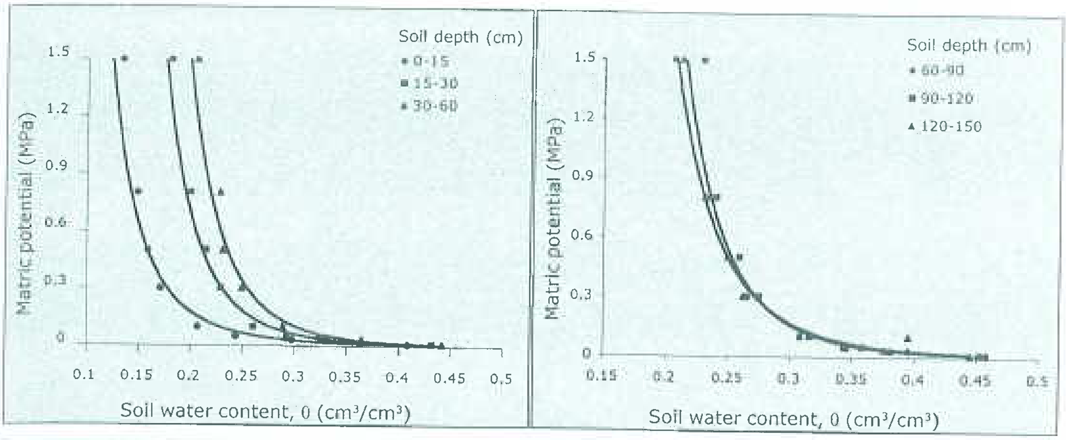

Fig.11a. Matric potential as a funtion of soil water content in Typic Paleustalf

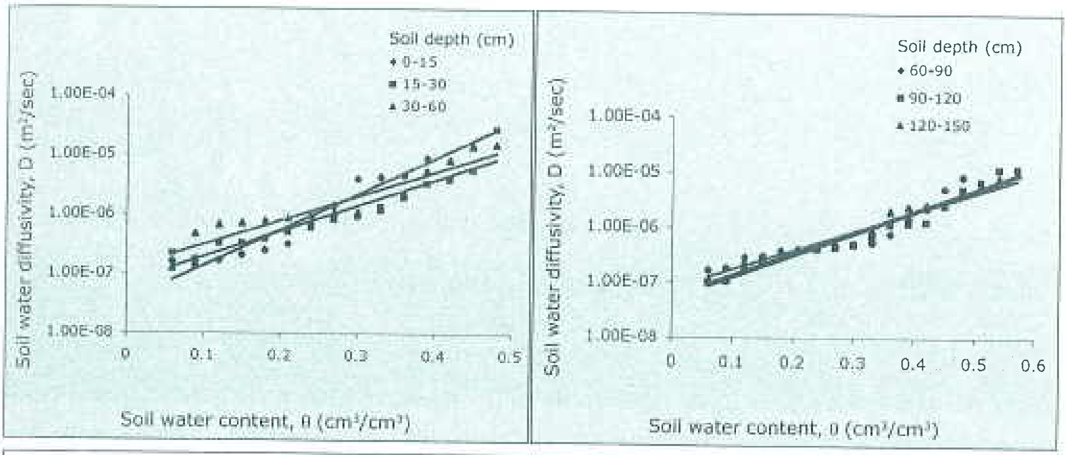

Fig.11b. Soil water diffusivity as a function of water content in Typic Paleustalf

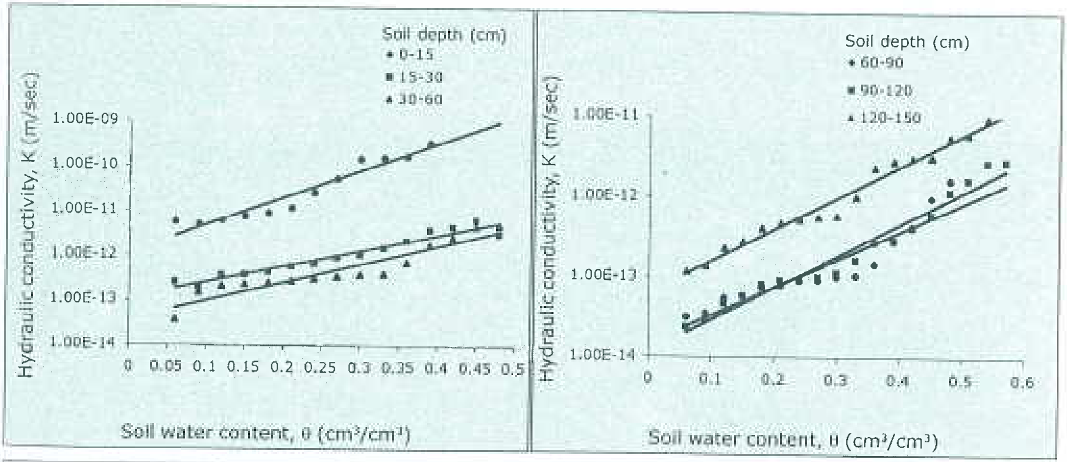

Fig.11c. Hydraulic conductivity as a function of water content in Typic Paleustalf

Table 14 (a): Physicochemical characteristics of Ultic Paleustalf

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC$_2$ (dS/m)	pH$_2$	OC (%)	Ca CO$_3$ (%)	CEC (me/100g)
0-15	17.3	8.4	14.7	59.6	sl	1.51	0.06	5.9	0.51	0.3	6.12
15-30	26.8	12.2	18.8	42.2	scl	1.52	0.08	5.6	0.13	0.5	8.98
30-60	28.5	10.9	14.5	46.1	scl	1.49	0.07	5.7	0.18	0.5	10.00
60-90	30.9	10.1	12.8	46.2	scl	1.55	0.07	6.0	0.18	0.7	12.20
90-120	31.6	10.2	10.2	48.0	scl	1.53	0.07	6.0	0.16	0.7	12.56
120-150	31.0	10.2	11.7	47.1	scl	1.54	0.07	6.0	0.17	0.8	13.40

Table 14 (b): Hydraulic characteristics of Ultic Paleustalf

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.987	0.402	0.170	0.060	0.110	$1.444 x 10^{-3}$	$1.692 x 10^{-4}$	$4.449 x 10^{-4}$	$1.285 x 10^{-6}$	$1.700 x 10^{-8}$
15-30	0.695	0.465	0.243	0.102	0.141	$1.667 x 10^{-3}$	$1.952 x 10^{-3}$	$5.606 x 10^{-4}$	$1.656 x 10^{-6}$	$2.200 x 10^{-8}$
30-60	0.816	0.521	0.241	0.122	0.119	$3.347 x 10^{-3}$	$3.920 x 10^{-4}$	$1.054 \ x \ 10^{-3}$	$1.964 x 10^{-6}$	$2.600 x 10^{-8}$
60-90	1.293	0.511	0.257	0.131	0.126	$1.263 x 10^{-3}$	$1.479 x 10^{-4}$	$3.131 x 10^{-4}$	$1.470 x 10^{-7}$	$2.000 x 10^{-9}$
90-120	1.793	0.506	0.259	0.139	0.120	$4.489 x 10^{-3}$	$5.257 x 10^{-4}$	$1.224 x 10^{-3}$	$5.731 x 10^{-6}$	$7.800 x 10^{-8}$
120-150	1.478	0.501	0.258	0.134	0.124	$3.24 x 10^{-3}$	$4.27 x 10^{-4}$	$1.341 x 10^{-3}$	$4.841 x 10^{-6}$	$7.210 x 10^{-8}$

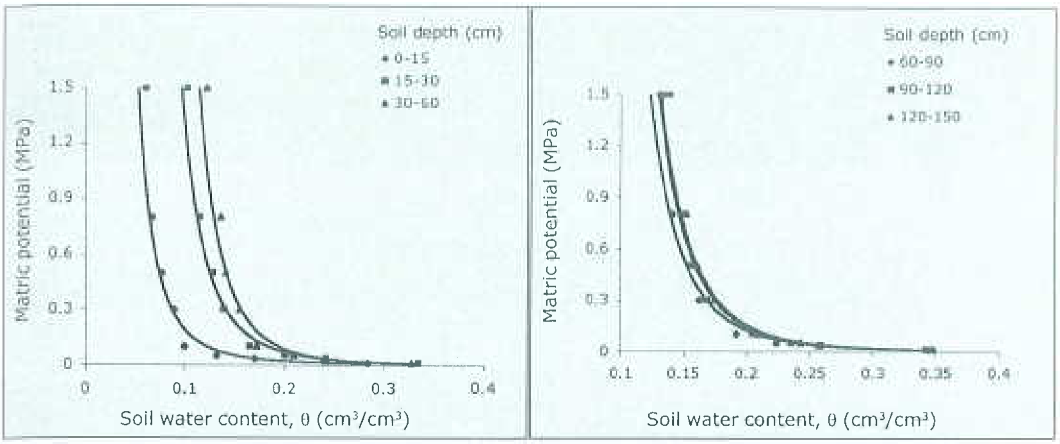

Fig.12a. Matric potential as a funtion of soil water content in Ultic Paleustalf

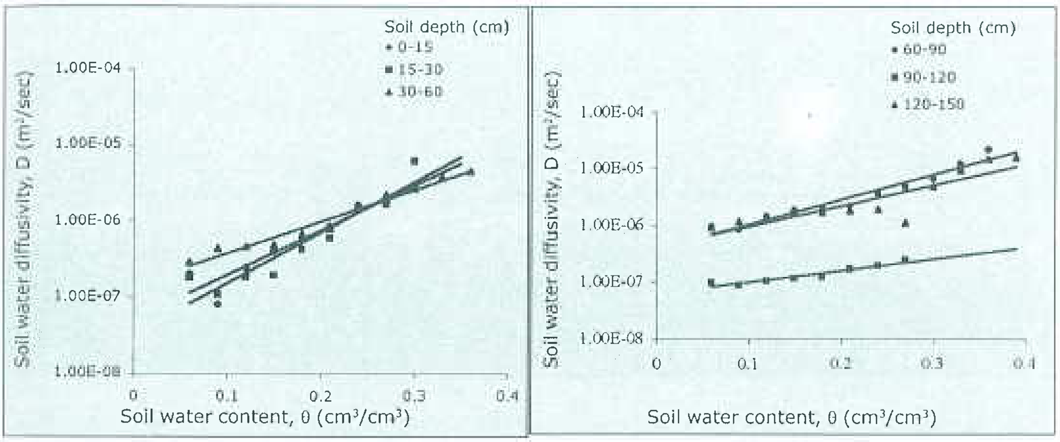

Fig. 12b. Soil water diffusivity as a function of water content in Ultic Paleustalf

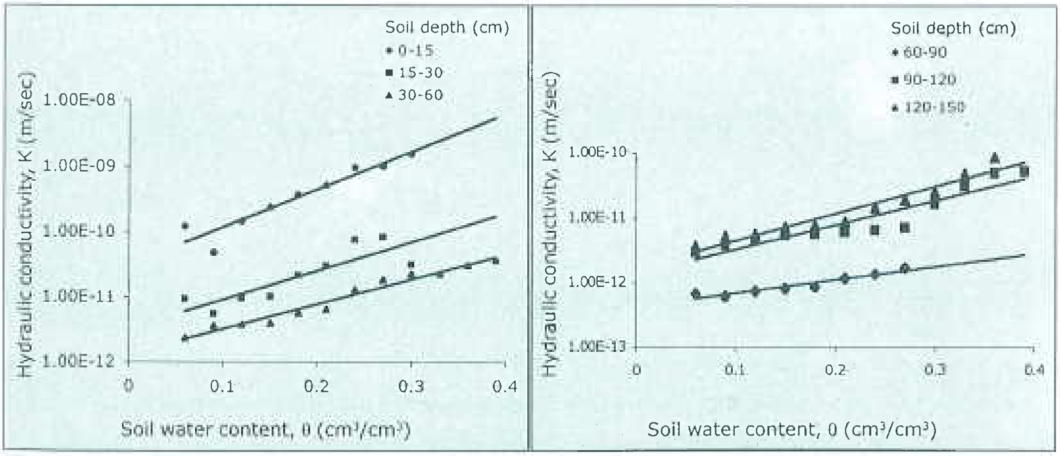

Fig.12c. Hydraulic conductivity as a function of water content in Ultic Paleustalf

Table 15 (a): Physicochemical characteristics of Kandic Paleustalf

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC$_2$ (dS/m)	pH$_2$	OC (%)	Ca CO$_3$ (%)	CEC (me/100g)
0-15	27.2	13.4	12.9	46.5	scl	1.46	0.05	6.3	0.32	1.4	9.96
15-30	32.9	16.3	11.8	39.0	scl	1.46	0.05	6.3	0.23	1.5	12.18
30-60	41.3	14.8	11.3	32.6	c	1.48	0.03	6.2	0.41	1.7	16.96
60-90	40.0	17.3	9.7	33.0	c	1.49	0.03	6.1	0.44	1.4	14.44
90-120	39.7	18.7	11.3	30.3	cl	1.50	0.05	6.1	0.30	1.7	14.44
120-150	53.0	26.8	11.3	8.9	c	1.51	0.03	6.1	0.30	0.3	22.18

Table 15 (b): Hydraulic characteristics of Kandic Paleustalf

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.713	0.492	0.243	0.139	0.104	9.278×10^{-4}	1.087×10^{-4}	3.965×10^{-4}	3.387×10^{-7}	4.640×10^{-9}
15-30	0.713	0.532	0.286	0.179	0.107	1.333×10^{-3}	1.562×10^{-4}	7.778×10^{-4}	1.409×10^{-7}	1.930×10^{-9}
30-60	0.269	0.580	0.313	0.173	0.140	1.019×10^{-3}	1.194×10^{-4}	3.397×10^{-4}	2.056×10^{-7}	2.817×10^{-9}
60-90	0.223	0.571	0.318	0.173	0.145	1.258×10^{-3}	1.474×10^{-4}	6.623×10^{-4}	8.376×10^{-7}	1.148×10^{-8}
90-120	0.157	0.596	0.345	0.174	0.171	1.149×10^{-3}	1.346×10^{-4}	4.714×10^{-4}	3.524×10^{-7}	4.828×10^{-9}
120-150	0.149	0.623	0.501	0.250	0.251	5.689×10^{-4}	6.663×10^{-5}	2.616×10^{-4}	1.448×10^{-7}	1.984×10^{-9}

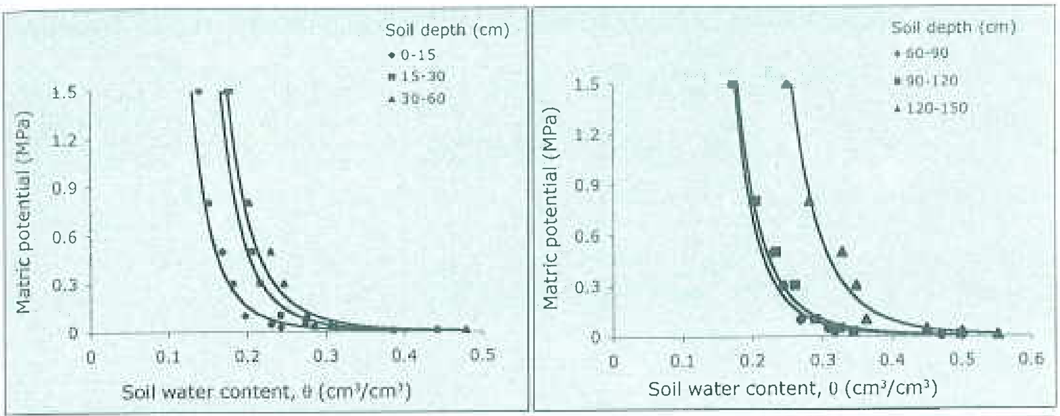

Fig.13a. Matric potential as a function of soil water content in Kandic Paleustalf

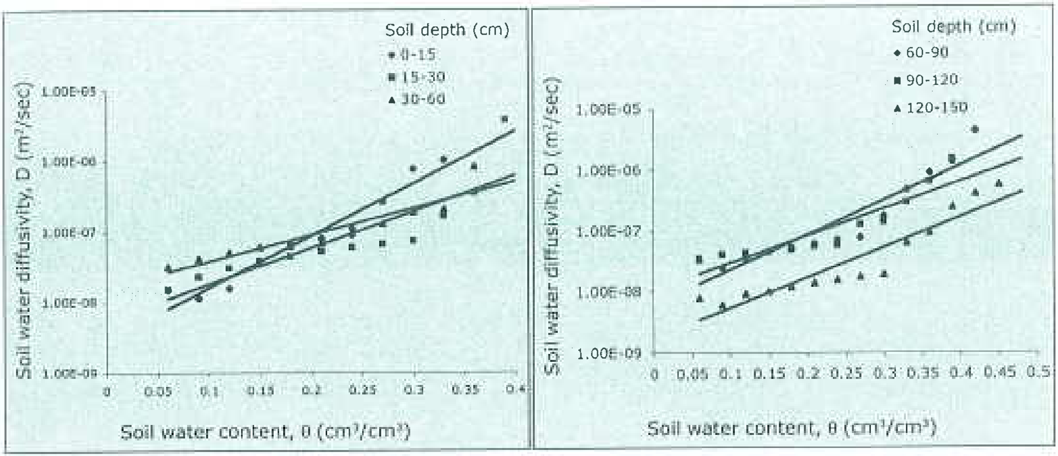

Fig.13b. Soil water diffusivity as a function of water content in Kandic Paleustalf

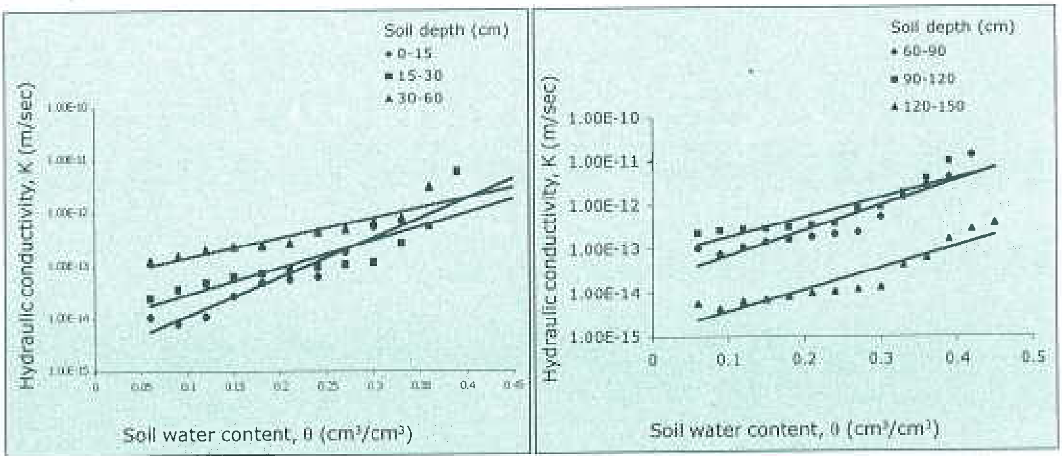

Fig.13c. Hydraulic conductivity as a function of water content in Kandic Paleustalf

Table 16 (a): Physico chemical characteristics of Rhodic Paleustalf

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	45.7	14.9	22.7	16.7	c	1.39	0.07	6.9	0.23	0.7	12.01
15-30	38.6	15.3	28.6	17.5	sc	1.40	0.10	6.9	0.67	1.0	12.53
30-60	37.6	14.9	28.8	18.8	sc	1.42	0.07	6.8	0.35	1.2	27.47
60-90	37.3	14.9	32.6	15.2	sc	1.43	0.07	6.7	0.23	1.3	24.04
90-120	45.8	12.9	25.8	15.5	c	1.44	0.08	6.6	0.19	1.4	23.36
120-150	40.8	12.9	30.6	15.7	c	1.46	0.07	6.6	0.20	1.4	13.30

Table 16 (b): Hydraulic characteristics of Rhodic Paleustalf

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/$\sqrt{s}$)	Pi ($\sqrt{m}$)	S (m/$\sqrt{s}$)	D (m/s)	Di (m)
0-15	1.047	0.561	0.330	0.189	0.141	2.349×10^{-3}	2.752×10^{-4}	9.397×10^{-4}	3.946×10^{-6}	5.400×10^{-8}
15-30	0.962	0.516	0.299	0.156	0.143	1.703×10^{-3}	1.995×10^{-4}	8.810×10^{-4}	1.509×10^{-6}	2.000×10^{-8}
30-60	0.927	0.502	0.269	0.164	0.100	2.761×10^{-3}	3.234×10^{-4}	1.155×10^{-3}	4.501×10^{-6}	6.100×10^{-8}
60-90	0.862	0.511	0.277	0.126	0.151	1.879×10^{-3}	2.201×10^{-4}	5.990×10^{-4}	2.225×10^{-6}	3.000×10^{-8}
90-120	0.722	0.541	0.326	0.180	0.146	2.744×10^{-3}	3.214×10^{-4}	1.187×10^{-3}	4.158×10^{-6}	5.700×10^{-8}
120-150	0.701	0.532	0.301	0.176	0.125	2.692×10^{-3}	3.104×10^{-4}	1.076×10^{-3}	4.108×10^{-6}	5.132×10^{-8}

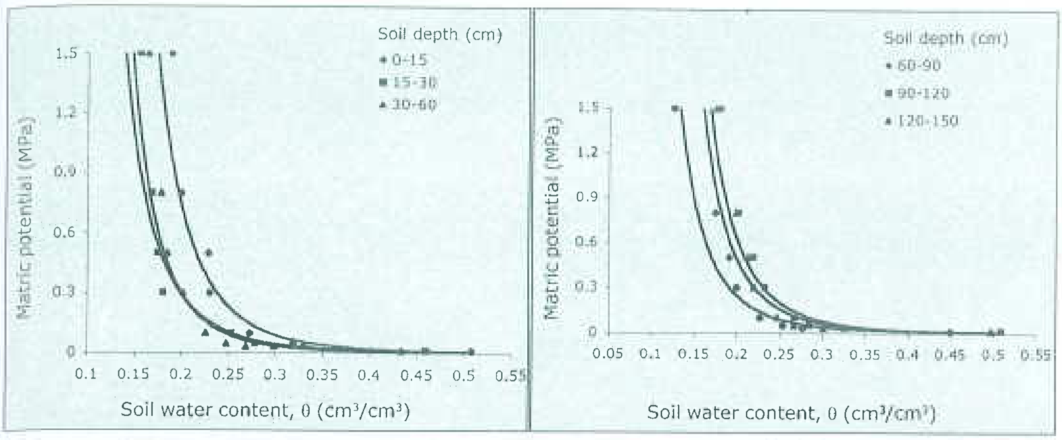

Fig.14a. Matric potential as a funtion of soil water content in Rhodic Paleustalf

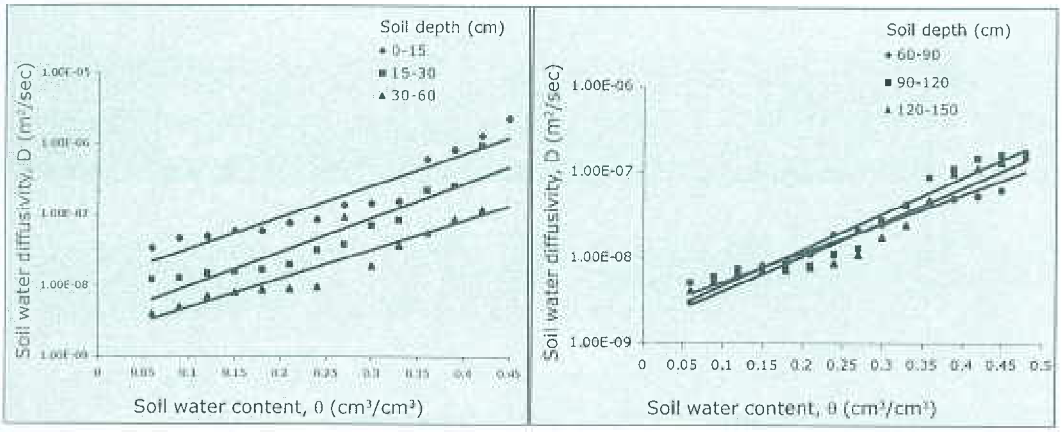

Fig.14b. Soil water diffusivity as a function of water content in Rhodic Paleustalf

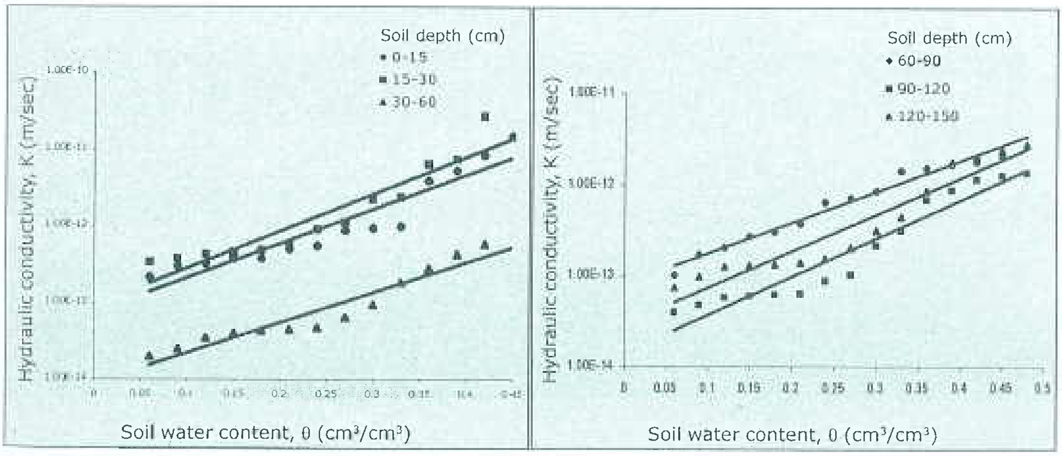

Fig.14c. Hydraulic conductivity as a function of water content in Rhodic Paleustalf

Table 17 (a): Physicochemical characteristics of Typic Rhodustalf

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	22.8	14.6	19.9	42.7	scl	1.48	0.85	7.0	0.47	1.4	13.97
15-30	33.9	15.9	16.6	33.6	scl	1.50	0.08	7.1	0.40	1.3	18.16
30-60	38.6	16.9	13.3	31.2	sc	1.52	0.28	7.3	0.34	1.0	20.18
60-90	39.8	14.9	12.4	32.9	sc	1.53	0.09	7.2	0.29	1.3	22.24
90-120	39.9	16.6	10.4	33.1	sc	1.54	0.32	7.4	0.28	1.1	24.23
120-150	39.5	16.7	11.2	32.6	sc	1.55	0.31	7.3	0.28	1.0	24.60

Table 17 (b): Hydraulic characteristics of Typic Rhodustalf

Soil depth (cm)	Ks (cm/hr)	θs (cm³/cm³)	θ (cm³/cm³) at 0.033 MPa	θ(cm³/cm³) at 1.5 MPa	Available water content (cm³/cm³)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.574	0.456	0.216	0.084	0.132	$1.512x10^{-3}$	$1.771x10^{-4}$	$5.843x10^{-4}$	$1.191x10^{-6}$	$1.600x10^{-8}$
15-30	0.552	0.571	0.331	0.200	0.131	$8.150x10^{-3}$	$9.545x10^{-4}$	$2.972x10^{-3}$	$2.560x10^{-7}$	$3.00x10^{-8}$
30-60	0.514	0.589	0.356	0.185	0.171	$1.869x10^{-3}$	$2.189x10^{-4}$	$6.465x10^{-4}$	$2.042x10^{-6}$	$2.80x10^{-8}$
60-90	0.488	0.604	0.363	0.173	0.190	$1.667x10^{-3}$	$1.952x10^{-4}$	$7.576x10^{-4}$	$1.487x10^{-6}$	$2.000x10^{-8}$
90-120	0.410	0.623	0.408	0.216	0.192	$1.768x10^{-3}$	$2.070x10^{-4}$	$8.081x10^{-4}$	$1.814x10^{-6}$	$2.400x10^{-8}$
120-150	0.412	0.613	0.389	0.197	0.192	$1.857x10^{-3}$	$2.010x10^{-4}$	$7.813x10^{-4}$	$1.742x10^{-6}$	$2.314x10^{-8}$

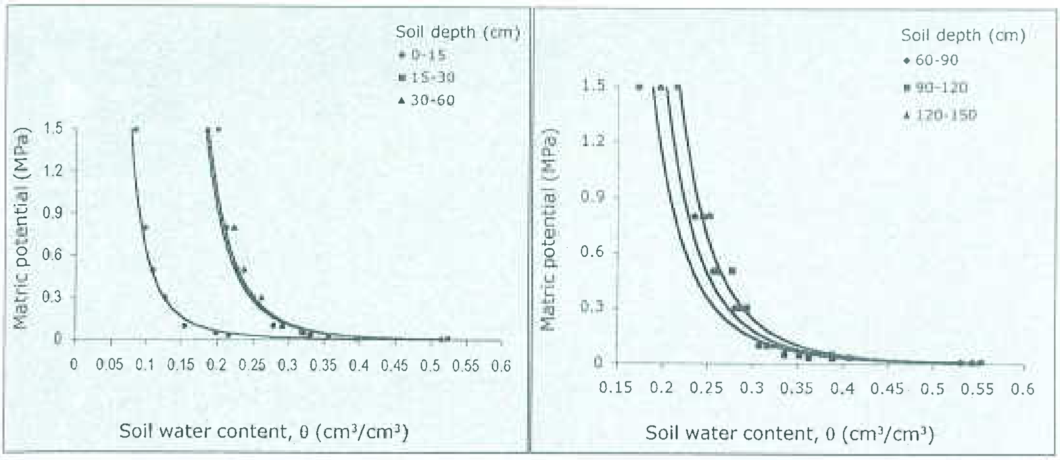

Fig.15a. Matric potential as a funtion of soil water content in Typic Rhodostalf

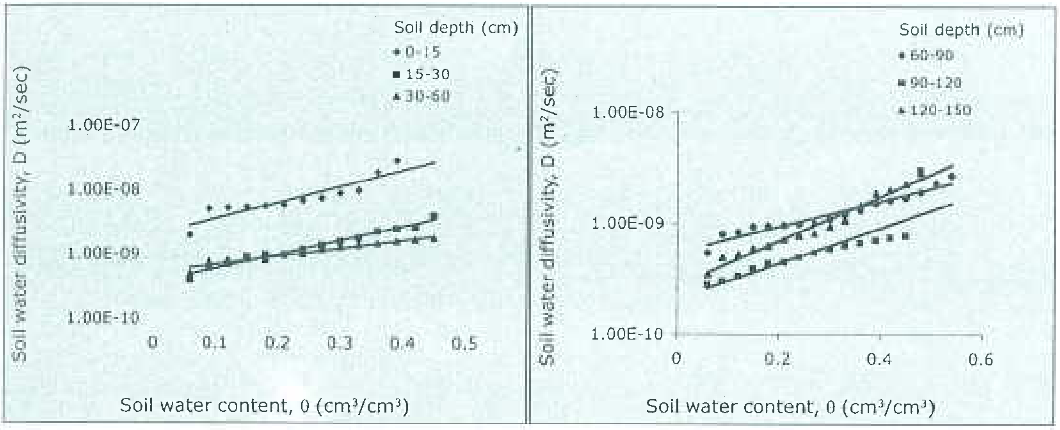

Fig.15b. Soil water diffusivity as a function of water content in Typic Rhodustalf

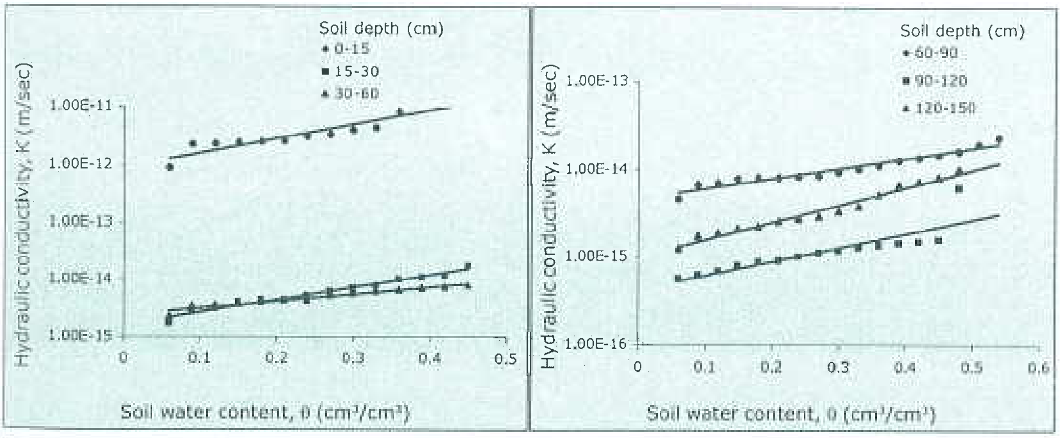

Fig.15c. Hydraulic conductivity as a function of water content in Typic Rhodustalf

Table 18 (a): Physicochemical characteristic of Typic Ochraqualf

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	41.4	28.6	6.3	23.7	c	1.40	0.07	5.8	0.51	1.7	20.92
15-30	37.5	27.0	5.1	30.4	cl	1.42	0.12	6.4	0.24	1.8	19.79
30-60	44.6	22.0	6.3	27.1	c	1.43	0.12	6.7	0.14	2.2	23.49
60-90	43.1	22.6	7.2	27.1	c	1.44	0.12	7.0	0.14	2.0	22.62
90-120	45.5	23.0	6.3	25.2	c	1.45	0.10	7.0	0.14	2.2	23.40
120-150	44.8	23.2	6.3	25.7	c	1.46	0.14	7.0	0.15	2.3	22.62

Table 18 (b): Hydraulic characteristics of Typic Ochraqualf

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.062	0.584	0.390	0.195	0.195	$6.901x10^{-4}$	$8.082x10^{-5}$	$6.211x10^{-4}$	$2.283x10^{-7}$	$3.128x10^{-9}$
15-30	0.060	0.553	0.379	0.184	0.195	$2.912x10^{-4}$	$3.411x10^{-5}$	$2.398x10^{-4}$	$2.970x10^{-8}$	$4.069x10^{-10}$
30-60	0.016	0.621	0.421	0.242	0.179	$4.126x10^{-4}$	$4.832x10^{-5}$	$6.704x10^{-4}$	$8.715x10^{-8}$	$1.194x10^{-9}$
60-90	0.015	0.603	0.426	0.234	0.192	$2.512x10^{-4}$	$2.942x10^{-5}$	$3.676x10^{-5}$	$3.888x10^{-8}$	$5.327x10^{-10}$
90-120	0.015	0.615	0.453	0.237	0.216	$4.830x10^{-4}$	$5.658x10^{-5}$	$6.901x10^{-4}$	$1.456x10^{-7}$	$1.995x10^{-9}$
120-150	0.015	0.620	0.436	0.236	0.200	$2.603x10^{-4}$	$3.048x10^{-5}$	$1.360x10^{-4}$	$3.695x10^{-8}$	$5.062xx10^{-1}$

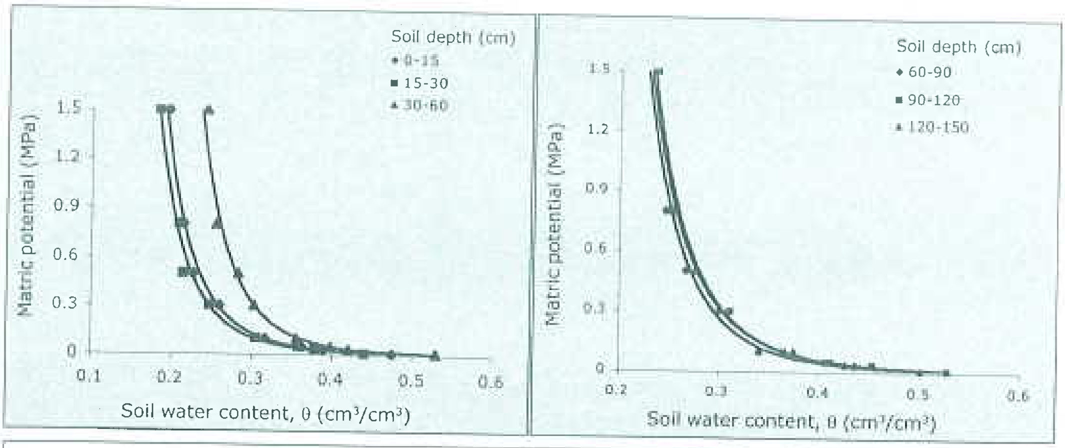

Fig.16a. Matric potential as a funtion of soil water content in Typic Ochraqualf

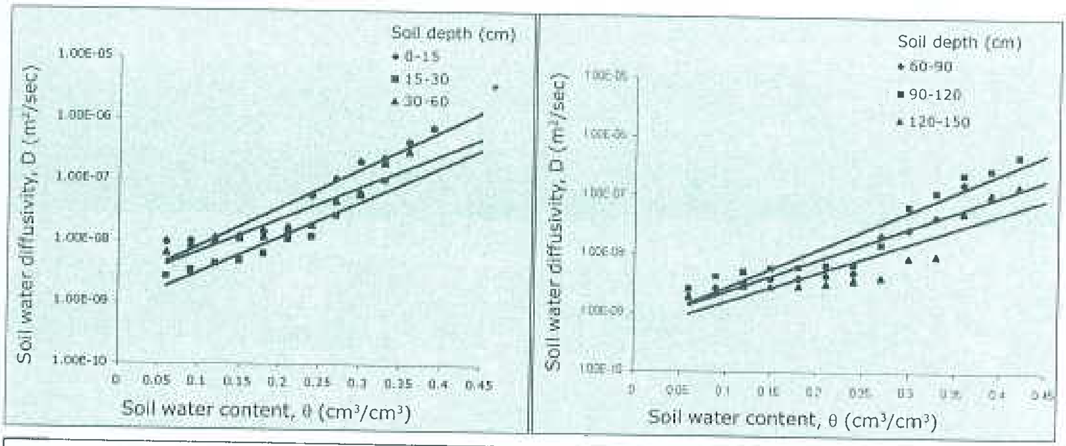

Fig.16b. Soil water diffusivity as a function of water content in Typic Ochraqualf

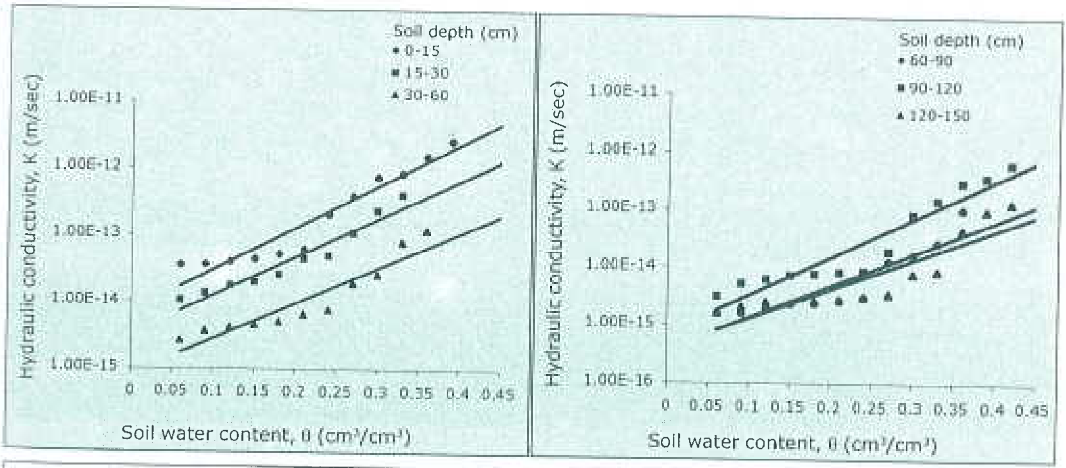

Fig.16c. Hydraulic conductivity as a function of water content in Typic Ochraqualf

Table 19 (a): Physico chemical characteristics of Aeric Ochraqualf

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC$_2$ (dS/m)	pH$_2$	OC (%)	CaCO$_3$ (%)	CEC (me/100g)
0-15	24.6	29.2	27.0	18.2	l	1.42	0.03	5.2	0.44	1.6	13.92
15-30	30.8	33.0	24.8	11.4	cl	1.44	0.03	5.5	0.29	1.5	17.0
30-60	30.2	36.4	18.8	14.6	cl	1.45	0.02	5.7	0.21	1.3	18.7
60-90	34.2	36.0	13.9	15.9	cl	1.47	0.02	6.0	0.20	1.1	18.7
90-120	30.2	32.8	19.2	17.8	cl	1.47	0.02	5.7	0.16	0.9	13.5
120-150	44.7	32.8	15.8	6.7	c	1.48	0.03	6.2	0.17	0.8	23.83

Table 19 (b): Hydraulic characteristics of Aeric Ochraqualf

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.309	0.537	0.345	0.098	0.247	1.225×10^{-3}	1.435×10^{-4}	1.225×10^{-3}	4.303×10^{-7}	5.895×10^{-9}
15-30	0.161	0.556	0.372	0.121	0.251	1.680×10^{-3}	1.968×10^{-4}	8.402×10^{-4}	8.611×10^{-7}	1.180×10^{-9}
30-60	0.123	0.553	0.336	0.126	0.210	9.696×10^{-4}	1.136×10^{-4}	4.593×10^{-4}	5.102×10^{-7}	6.990×10^{-9}
60-90	0.078	0.578	0.352	0.172	0.180	8.719×10^{-4}	1.021×10^{-4}	4.671×10^{-4}	3.029×10^{-7}	4.150×10^{-9}
90-120	0.076	0.532	0.346	0.128	0.218	5.667×10^{-4}	6.637×10^{-5}	2.667×10^{-4}	1.413×10^{-7}	1.936×10^{-9}
120-150	0.038	0.663	0.462	0.235	0.227	4.833×10^{-4}	5.661×10^{-5}	2.667×10^{-4}	1.134×10^{-7}	1.554×10^{-9}

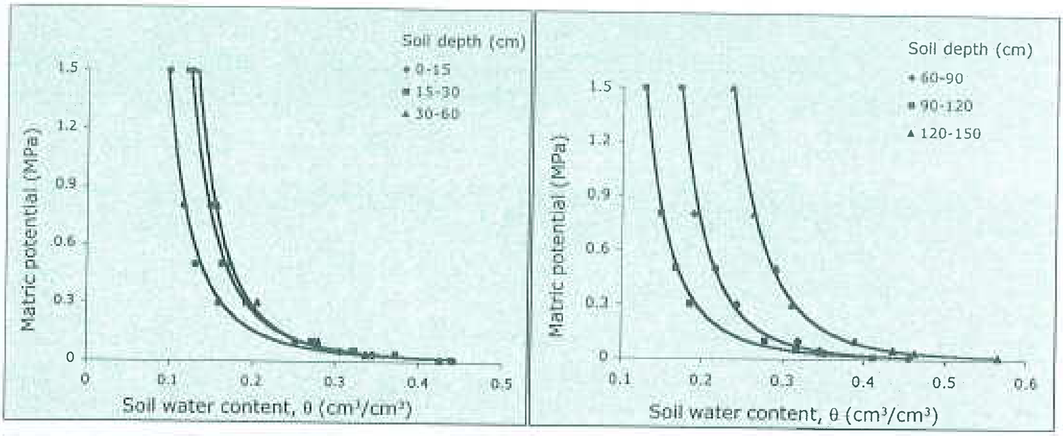

Fig.17a. Matric potential as a funtion of soil water content in Aeric Ochraqualf

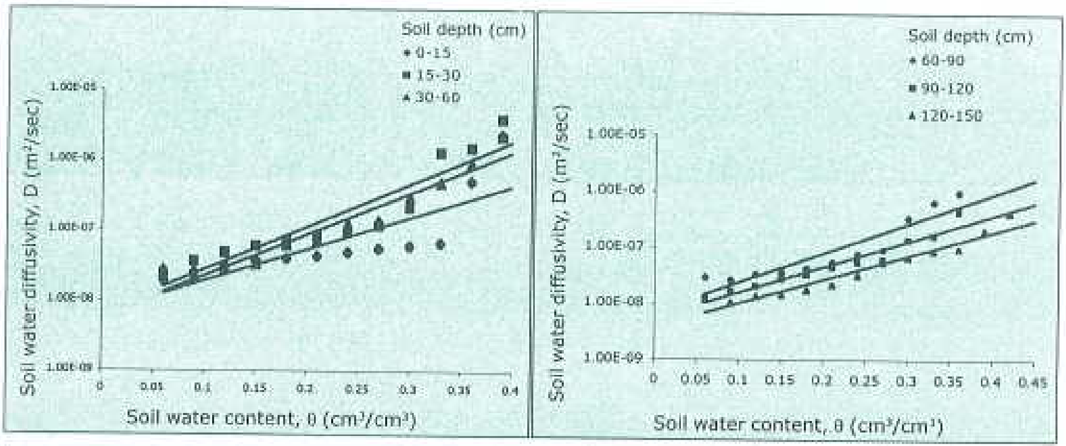

Fig.17b. Soil water deffusivity as a function of water content in Aeric Ochraqualf

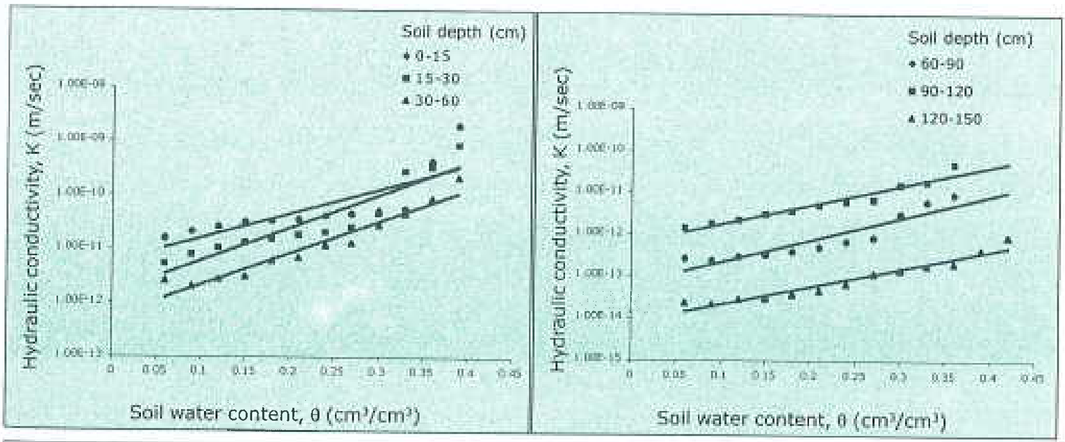

Fig.17c. Hydraulic conductivity as a function of water content in Aeric Ochraqualf

Table 20: Water storage capacity of the alfisol profiles

Name of the subgroup	Profile water storage capacity (cm/m depth)	Category for profile water capacity
Ultic Paleustalf	12.32	Medium
Typic Paleustalf	16.18	High
Rhodic Paleustalf	11.90	Medium
Typic Rhodustalf	16.70	High
Typic Ochraqualf	19.14	High
Aeric Ochraqualf	21.35	Very high
Typic Haplustalf	22.78	Very high
Kandic Paleustalf	13.43	Medium

Table 21: Erosion Index of the alfisol profiles

Soil subgroup	Erosion index			
	Soil depth (cm)			Mean
	0- 15	15 -30	30 –150	
Ultic Paleustalf	14.47	7.68	8.29	10.15
Typic Paleustalf	24.40	7.26	10.00	13.89
Rhodic Paleustalf	2.99	13.54	9.69	8.74
Typic Rhodustalf	15.00	17.53	9.14	13.89
Typic Ochraqualf	21.24	18.89	16.09	18.74
Aeric Ochraqualf	23.80	19.94	21.66	21.80
Typic Haplustalf	20.93	18.90	19.96	19.93
Kandic Paleustalf	22.00	16.62	14.49	17.70
Mean	18.10	15.06	13.67	
C D (P=0.05) to compare	soil subgroup means:	1.37		
	soil depth means:	0.84		
	subgroup x depth:	0.63		

water storage capacity. Very high profile water storage capacity was observed in Aeric Ochraqualf and Typic Haplustalf. High profile water storage capacity was found in Typic Paleustalf, Typic Rhodustalf and Typic Ochraqualf. The storage capacity was medium in Ultic Paleustalf, Rhodic Paleustalf and Kandic Paleustalf.

4.2.3 Erosion Index (EI):

Mean values of EI for Alfisols are presented in Table 21. In 0-15 cm soil depth, EI values varied from 2.99 in Rhodic Paleustalf to 24.40 in Typic Paleustalf. No significant difference was observed between Ultic Paleustalf and Typic Rhodustalf, and among Typic Ochraqualf, Typic Haplustalf and Kandic Paleustalf. In 15-30 cm soil depth, the highest EI of 19.94 was observed in Aeric Ochraqualf and the lowest EI of 7.26 was in Typic Paleustalf. No significant difference was observed between Ultic Paleustalf and Typic Paleustalf, between Typic Rhodustalf and Kandic Paleustalf, between Typic Rhodustalf and Kandic Paleustalf, between Typic Rhodustalf and Typic Ochraqualf, and among Typic Occhraqualf, Aeric Ochraqualf and Typic Haplustalf. Significantly higher value of mean EI was observed for 0-15 cm soil depth.

4.2.4 Water management implications

Application of organic materials like FYM or compost to all the subgroups, and particularly to Ultic Paleustalf and Rhodic Paleustalf, will improve the water retention capacity of soils. Application of lime in appropriate amount to Aeric Ochraqualf, Typic Ochraqualf, Ultic Paleustalf, Typic Paleustalf and Typic Haplustalf will improve crop productivity of these subgroups. Data on soil water retention and available water content suggest that light and frequent irrigation and use of mulches will be useful to improve use efficiency of applied water in Ultic Paleustalf, Kandic Paleustalf, Typic Rhodustalf, Rhodic Paleustalf and Typic Paleustalf. The frequency of irrigation in these soils may be reduced through use of mulches. Use of drip or sprinkler irrigation will be effective for increasing water use efficiency in these soil subgroups. Medium to heavy irrigation applied at long intervals will be effective to improve use efficiency of applied water in Typic Haplustalf, Aeric Ochraqualf and Typic Ochraqualf .

Data on penetrability, intrinsic penetrability and sorptivity revealed that adoption of suitable management practices for *in situ* conservation of water will be necessary in Typic Ochraqualf, Typic Haplustalf, Kandic Paleustalf and Aeric Ochraqualf to improve water use efficiency. Modification of soil texture with addition of appropriate amendments will help in improving water use efficiency and crop productivity of these soil subgroups.

In Aeric Ochraqualf and Typic Haplustalf, cultivation of a second crop without irrigation will be possible after rainy season provided it is sown immediately after the harvest of *kharif* crop. In Typic Paleustalf, Typic Rhodustalf and Typic Ochraqualf, a second crop without irrigation is possible either as a *paira* crop or with mulching.

4.3 Soil Order: ENTISOL

These are recently formed soils with little or no evidence of development of pedogenic horizons. They have ochric epipedon and some times anthropic epipedon. These soils are on steep, actively eroding slopes, on flood plains or glacial outwash plains that receive new deposits of alluvium. They are formed on a variety of climatic conditions. The parent material is also variable which may be recent alluvium, sand dunes or even a variety of rocks. Large areas of Entisols in alliuvial bottom lands are cultivated for a variety of grain and vegetable crops and used for pastures.

Based on moisture, temperature, fluvial nature and extreme texture, the entisols in Orissa have been divided into 3 suborders, viz. Aquents, Orthents and Psamments.

Aquents: These are seasonally saturated with water and show signs of wetness. The dominant hue is neutral or lighter than 10 Y and chroma is usually less than 2. Colours change on exposure to air, subsoils have distinct or prominent mottling.

Orthents: They are better drained soils than Aquents and show regular decrease of organic matter with depth. These are formed on recent erosional surfaces. They are not present in areas that have a high water table or on shifting or stabilized sand dunes.

Psamments: Psamments are coarse-textured (sandy) soils with excessive drainage. They also have low water holding capacity. These are mainly shifting or stabilized sand dunes or sands that were sorted by water and are on the sandy natural levels or beaches.

Great groups:

Fluvaquents: These are primarily the wet soils of flood plains and delta of middle and low latitudes. Most of them have fine or coarse stratification. They have organic carbon content that dcreases irregularly with depth below 25 cm or that remains more than 0.2 percent to a depth of 1.25 m.

Ustorthents: They have an Ustic soil moisture regime and warmer temperture regime. They are mostly the lithosols and regosols found as soft sedimentary deposits. Their EC is less than 2 dS/m.

Ustipsamments: They have an ustic moisture regime and frigid to hyperthermic temperature regime. These soils are freely drained sand, have mostly grasses and drought tolerant forests of small and scattered trees.

Dominating subgroups : There are 2 subgroups under Ustorthent and one each under Tropaquent and Ustipsamment. They are:

1. Typic Ustorthent
2. Lithic Ustorthent
3. Aeric Fluvaquent
4. Typic Ustipsamment

4.3.1 Physicochemical and hydrological properties : Physicochemical and hydrological properties of entisols are presented in Tables 22 to 25. Aeric Fluvaquent was clay loam to clay in texture with clay content ranging from 34.26 to 49.16%. Typic Ustorthent and Lithic Ustorthent were loam to clay loam in texture with clay content varying from 26.2 to 38.6%. Typic Ustipsamment was loamy sand to sandy clay loam in texture with clay content ranging from 9.66 to 26.02%. Highest bulk density was observed in Typic Ustipsamment, where it varied from 1.52 to 1.56 Mgm^{-3}. Lowest bulk density was observed in Aeric Fluvaquent, where it ranged from 1.42 to 1.47 $Mgm^{-3.}$ Generally, pH increased with soil depth. In 0-15 cm soil layer, highest pH of 7.5 was found in Typic Ustipsamment and the lowest pH of 5.3 in Typic Ustorthent. In 120-150 cm soil depth, pH varied from 5.9 to 7.9. Data on electrical conductivity showed that all subgroups except Aeric Fluvaquent were free from salinity problem. EC_2 of the Aeric Fluvaquent profile varied from 1.35 to 3.80 dS/m indicating moderate level of salinity. In general, all subgroups were low in organic carbon (OC). OC content varied from 0.120 to 0.673%. Highest OC content was observed in Aeric Fluvaquent and the lowest in Typic Ustipsamment. All the subgroups were non-calcareous in nature and their $CaCO_3$ content varied from 0.10 to 2.6 per cent. Cation exchange capacity (CEC) of the soil subgroups varied widely. The highest was observed in Aeric Fluvaquent, where it varied from 21.79 to 32.53 me/100g, while the lowest CEC was observed in Typic Ustipsamment where it ranged from 3.92 to 13.63 me/100g.

Data on saturated hydraulic conductivity (Ks), moisture retention at saturation, 0.033 MPa, and 1.5 MPa and available water content are presented in Tables 22b to 25b. The highest saturated hydraulic conductivity (4.428 cm/hr) was observed in Typic Ustipsamment and the lowest Ks (0.003 cm/hr) was in Aeric Fluvaquent subgroup. In the other two subgroups, it varied from 0.030 to 0.084 cm/hr. Soil water retention characteristics (ψ–θ relationships) of the soils are presented in Fig 18a to 21a. At 0.033 MPa, water retention was the highest in Aeric Fluvaquent

Table 22 (a): Physicochemical characteristics of Typic Ustorthent

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	26.2	29.0	10.6	34.2	l	1.44	0.05	5.3	0.48	0.9	12.7
15-30	26.2	28.0	10.2	35.6	l	1.45	0.04	5.8	0.29	0.7	12.7
30-60	32.6	25.9	8.7	32.8	Cl	1.46	0.04	5.9	0.21	0.8	16.7
60-90	35.8	29.7	7.9	26.6	Cl	1.48	0.04	6.0	0.15	0.8	16.44
90-120	40.2	24.0	7.6	28.2	C	1.50	0.04	5.9	0.14	0.8	18.43
120-150	38.0	23.6	7.3	31.1	Cl	1.52	0.04	5.9	0.14	0.9	17.70

Table 22 (b): Hydraulic characteristics of Typic Ustorthent

Soil depth (cm)	Ks (cm/hr)	θs (cm³/cm³)	θ (cm³/cm³) at 0.033 MPa	θ(cm³/cm³) at 1.5 MPa	Available water content (cm³/cm³)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.074	0.523	0.328	0.129	0.199	$1.435x10^{-3}$	$1.681x10^{-4}$	$4.901x10^{-4}$	$7.535x10^{-7}$	$1.032x10^{-8}$
15-30	0.071	0.501	0.291	0.134	0.157	$1.929x10^{-3}$	$2.259x10^{-4}$	$7.715x10^{-4}$	$1.931x10^{-6}$	$2.645x10^{-8}$
30-60	0.056	0.521	0.342	0.168	0.174	$1.293x10^{-3}$	$1.514x10^{-4}$	$6.155x10^{-4}$	$9.284x10^{-7}$	$1.272x10^{-8}$
60-90	0.037	0.533	0.394	0.168	0.226	$4.344x10^{-4}$	$5.088x10^{-5}$	$2.085x10^{-4}$	$6.568x10^{-8}$	$8.998x10^{-10}$
90-120	0.030	0.563	0.407	0.205	0.202	$2.767x10^{-4}$	$3.240x10^{-5}$	$2.646x10^{-4}$	$3.034x10^{-8}$	$4.157x10^{-10}$
120-150	0.032	0.566	0.403	0.208	0.195	$2.907x10^{-4}$	$3.405x10^{-5}$	$1.539x10^{-4}$	$4.587x10^{-8}$	$6.284x10^{-10}$

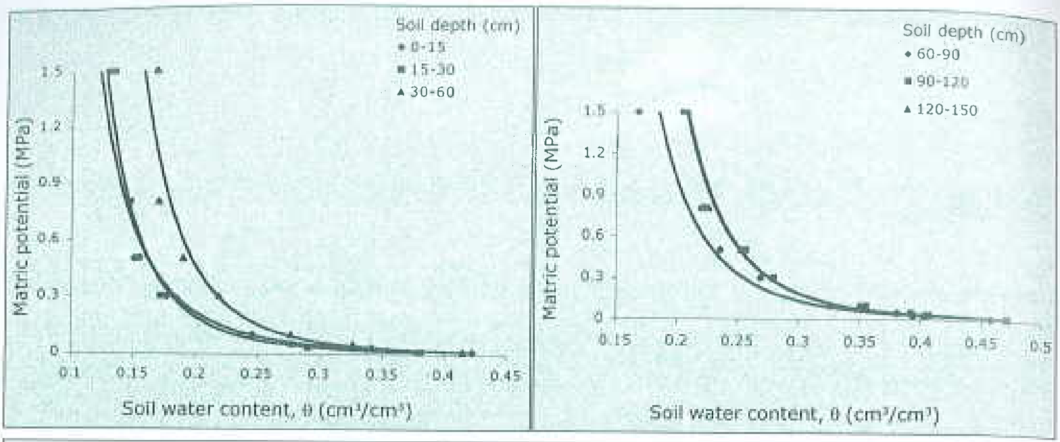

Fig.18a. Matric potential as a funtion of soil water content in Typic Ustorthent

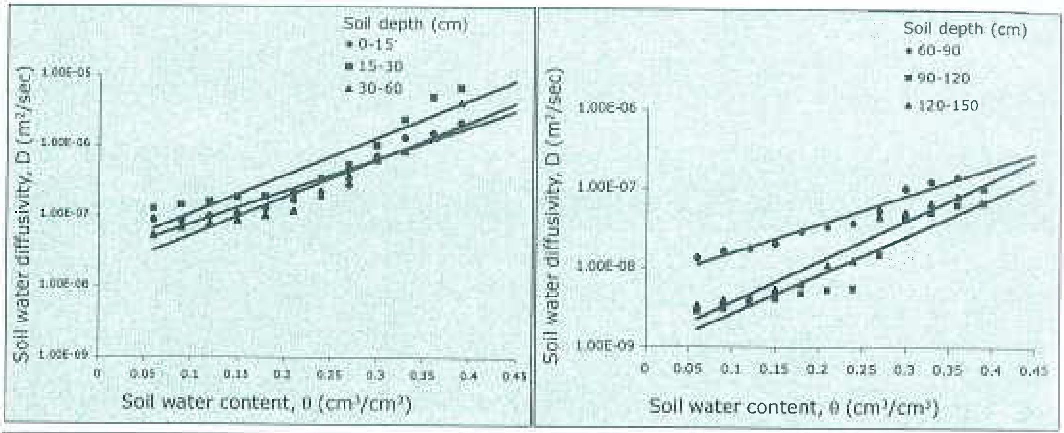

Fig.18b. Soil water diffusivity as a function of water content in Typic Ustorthent

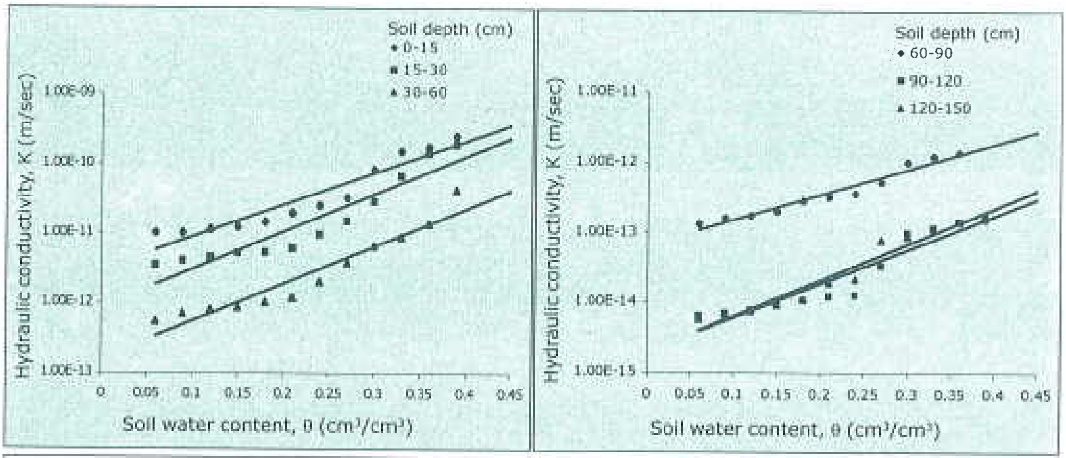

Fig.18c. Hydraulic conductivity as a function of water content in Typic Ustorthent

Table 23 (a): Physicochemical characteristics of Lithic Ustorthent

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC_2 (dS/m)	pH_2	OC (%)	$CaCO_3$ (%)	CEC (me/100g)
0-15	33.2	26.0	27.6	13.2	cl	1.44	0.11	5.8	0.51	1.8	16.44
15-30	36.6	24.2	29.4	9.8	cl	1.45	0.08	6.6	0.32	2.4	17.44
30-60	38.2	22.8	28.7	9.9	cl	1.46	0.13	6.9	0.21	2.6	19.79

Table 23 (b): Hydraulic characteristics of Lithic Ustorthent

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/$\sqrt{s}$)	Pi ($\sqrt{m}$)	S (m/$\sqrt{s}$)	D (m/s)	Di (m)
0-15	0.089	0.588	0.400	0.174	0.226	7.454×10^{-4}	8.730×10^{-5}	3.354×10^{-4}	1.896×10^{-7}	2.598×10^{-9}
15-30	0.083	0.569	0.389	0.180	0.209	5.544×10^{-4}	6.493×10^{-5}	2.218×10^{-4}	1.043×10^{-7}	1.429×10^{-9}
30-60	0.072	0.602	0.401	0.202	0.199	3.940×10^{-4}	4.614×10^{-5}	2.912×10^{-4}	7.501×10^{-8}	1.028×10^{-9}

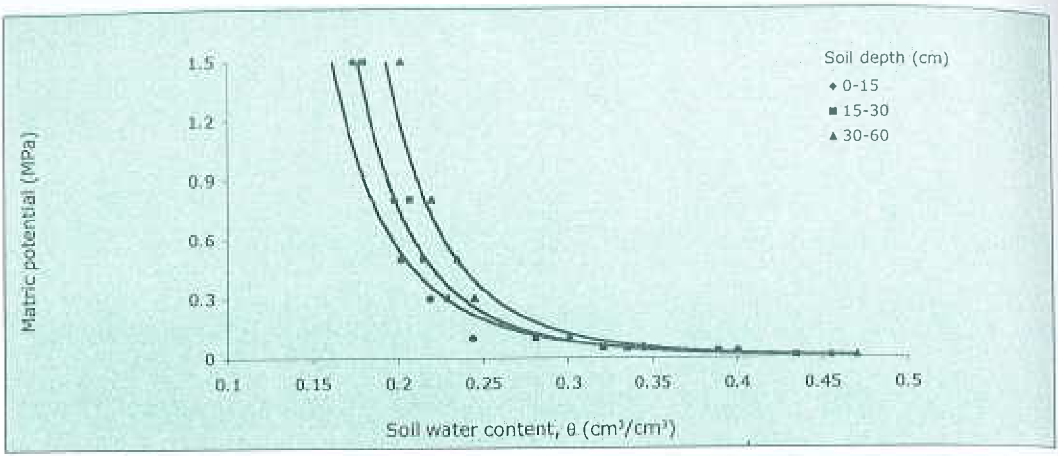

Fig.19a. Matric potential as a funtion of soil water content in Lithic Ustorthent

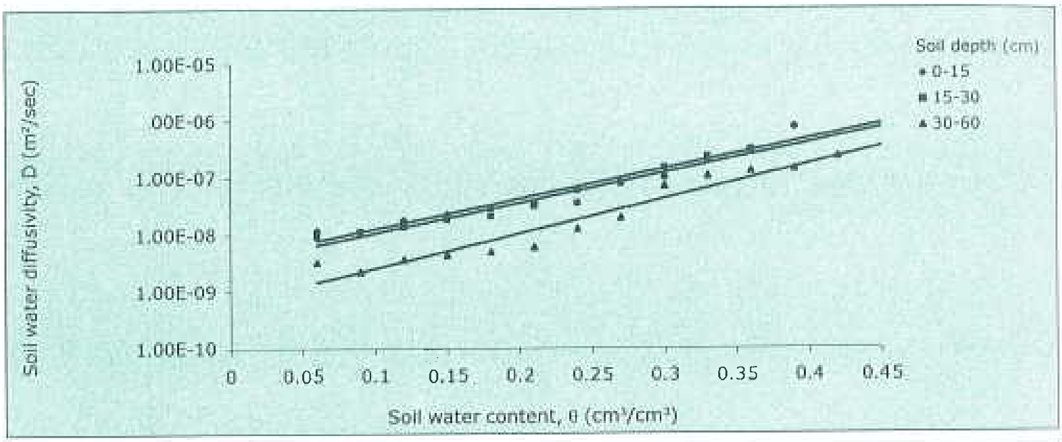

Fig.19b. Soil water diffusivity as a function of water content in Lithic Ustorthent

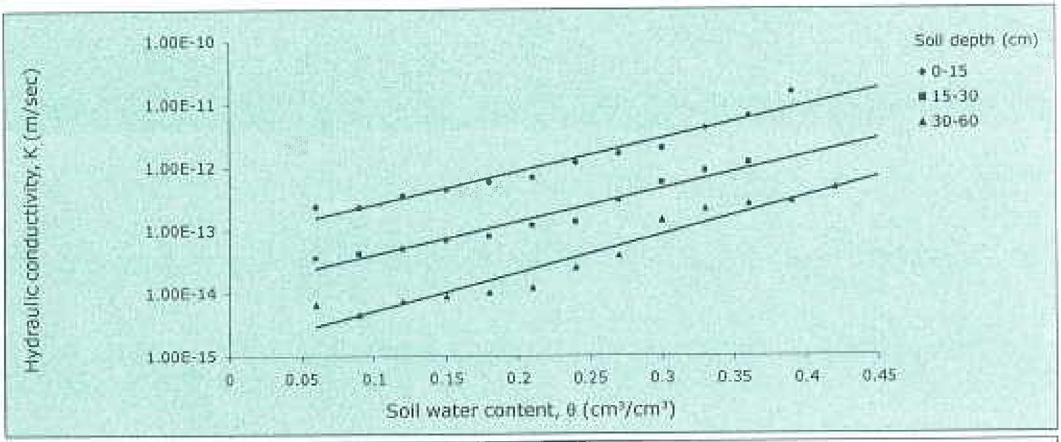

Fig.19c. Hydraulic conductivity as a function of water content in Lithic Ustorthent

Table 24 (a): Physicochemical characteristics of Aeric Fluvaquent

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC$_2$ (dS/m)	pH$_2$	OC (%)	CaCO$_3$ (%)	CEC (me/100g)
0-15	34.3	24.8	14.6	26.3	Cl	1.42	1.35	5.6	0.67	1.1	21.79
15-30	43.1	29.2	9.4	18.3	C	1.43	1.75	6.5	0.29	1.2	26.53
30-60	45.8	27.0	8.8	18.4	C	1.44	2.12	7.1	0.13	1.2	25.85
60-90	48.0	26.0	6.8	19.2	C	1.43	2.85	7.5	0.16	1.4	31.93
90-120	49.2	27.1	5.7	18.0	C	1.45	3.10	7.4	0.13	1.7	32.53
120-150	49.1	27.2	7.2	16.5	C	1.47	3.80	7.5	0.14	1.0	30.44

Table 24 (b): Hydraulic characteristics of Aeric Fluvaquent

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.003	0.517	0.399	0.186	0.213	1.347×10^{-4}	1.578×10^{-5}	9.798×10^{-5}	1.10×10^{-8}	1.594×10^{-10}
15-30	0.003	0.545	0.453	0.226	0.227	7.225×10^{-5}	8.462×10^{-6}	1.084×10^{-4}	2.00×10^{-9}	2.748×10^{-11}
30-60	0.004	0.652	0.498	0.262	0.236	6.633×10^{-5}	7.769×10^{-6}	6.633×10^{-5}	1.00×10^{-9}	2.003×10^{-11}
60-90	0.008	0.638	0.568	0.300	0.268	6.124×10^{-5}	7.172×10^{-6}	4.894×10^{-5}	1.00×10^{-9}	2.173×10^{-11}
90-120	0.009	0.633	0.578	0.309	0.269	5.388×10^{-5}	6.311×10^{-6}	7.348×10^{-5}	8.847×10^{-10}	1.214×10^{-11}
120-150	0.009	0.646	0.571	0.297	0.280	5.498×10^{-5}	7.011×10^{-6}	7.484×10^{-5}	8.791×10^{-10}	1.314×10^{-11}

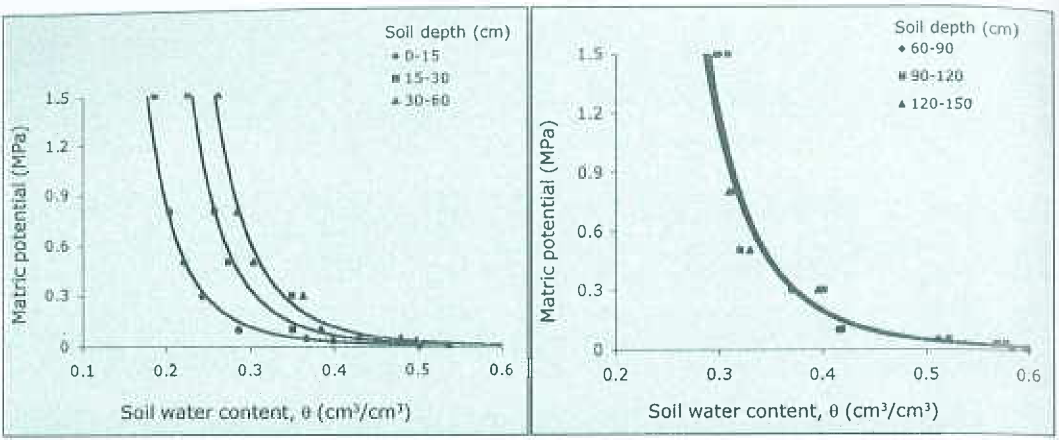

Fig.20a. Matric potential as a funtion of soil water content in Aeric Fluvaquent

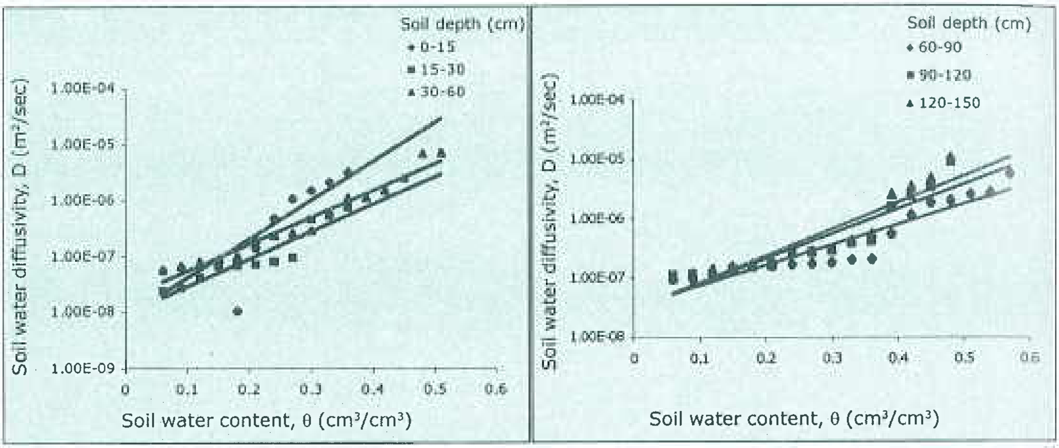

Fig.20b. Soil water diffusivity as a function of water content in Aeric Fluvaquent

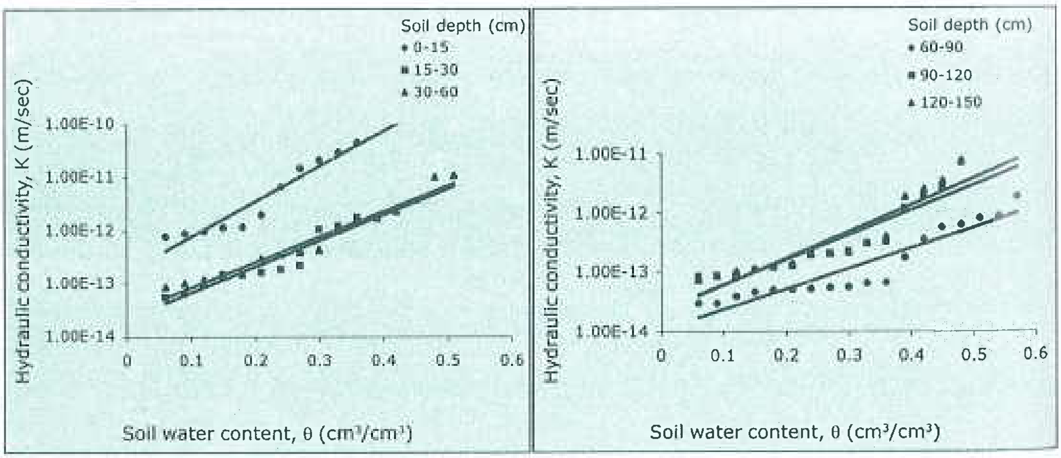

Fig.20c. Hydraulic conductivity as a function of water content in Aeric Fluvaquent

Table 25 (a) : Physicochemical characteristics of Typic Ustipsamment

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC$_2$ (dS/m)	pH$_2$	OC (%)	CaCO$_3$ (%)	CEC (me/100g)
0-15	9.7	4.5	30.5	55.3	ls	1.52	0.07	7.1	0.15	0.3	3.92
15-30	15.1	5.3	27.5	52.1	sl	1.54	0.08	6.9	0.16	0.1	6.61
30-60	19.7	5.8	27.9	46.7	sl	1.54	0.07	6.7	0.16	0.3	9.79
60-90	19.9	7.0	13.9	59.2	sl	1.55	0.14	6.6	0.22	0.2	9.61
90-120	24.5	6.4	15.3	53.8	scl	1.56	0.12	6.6	0.12	0.5	12.48
120-150	26.0	9.6	20.9	43.5	scl	1.56	0.12	6.7	0.18	0.7	13.83

Table 25 (b): Hydraulic characteristics of Typic Ustipsamment

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	4.428	0.362	0.107	0.041	0.066	5.818×10^{-3}	6.814×10^{-4}	1.715×10^{-3}	1.327×10^{-5}	1.818×10^{-7}
15-30	1.296	0.385	0.130	0.065	0.065	2.346×10^{-3}	2.748×10^{-4}	7.201×10^{-4}	1.290×10^{-6}	1.767×10^{-8}
30-60	0.652	0.426	0.158	0.090	0.068	1.657×10^{-3}	1.941×10^{-4}	5.605×10^{-4}	1.060×10^{-6}	1.452×10^{-8}
60-90	0.544	0.445	0.188	0.104	0.084	1.655×10^{-3}	1.939×10^{-4}	5.417×10^{-4}	1.108×10^{-6}	1.518×10^{-8}
90-120	0.326	0.504	0.209	0.111	0.098	2.245×10^{-3}	2.630×10^{-4}	8.165×10^{-4}	3.232×10^{-6}	4.428×10^{-8}
120-150	0.328	0.515	0.238	0.120	0.118	9.199×10^{-4}	1.077×10^{-4}	3.569×10^{-4}	3.939×10^{-7}	5.396×10^{-9}

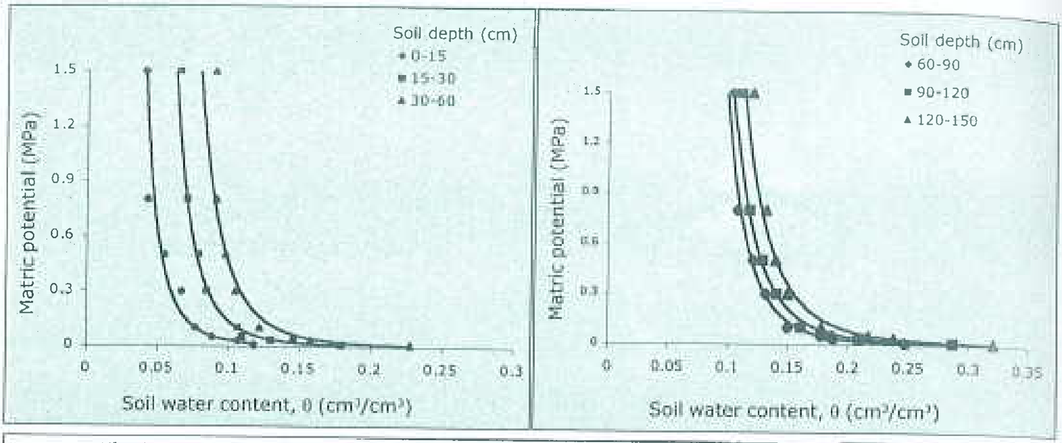

Fig.21a. Matric potential as a funtion of soil water content in Typic Ustipsamment

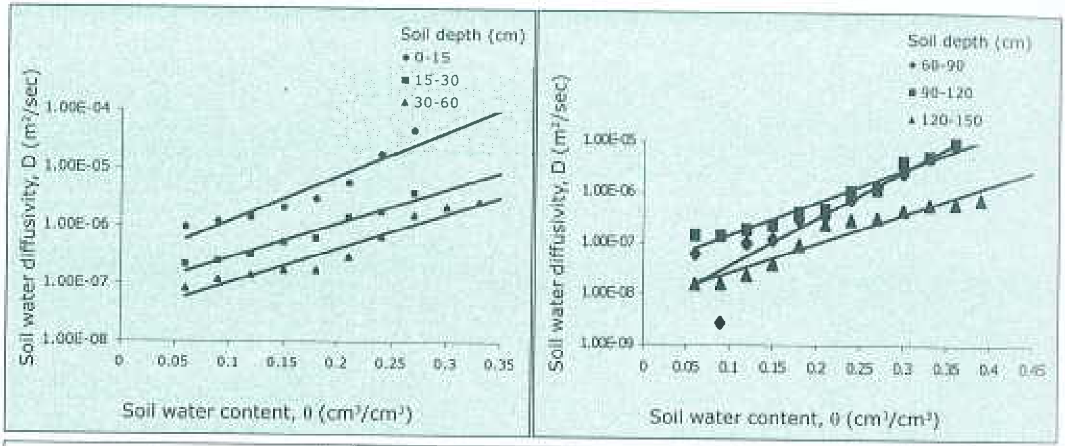

Fig.21b. Soil water diffusivity as a funct ion of water content in Typic Ustipsamment

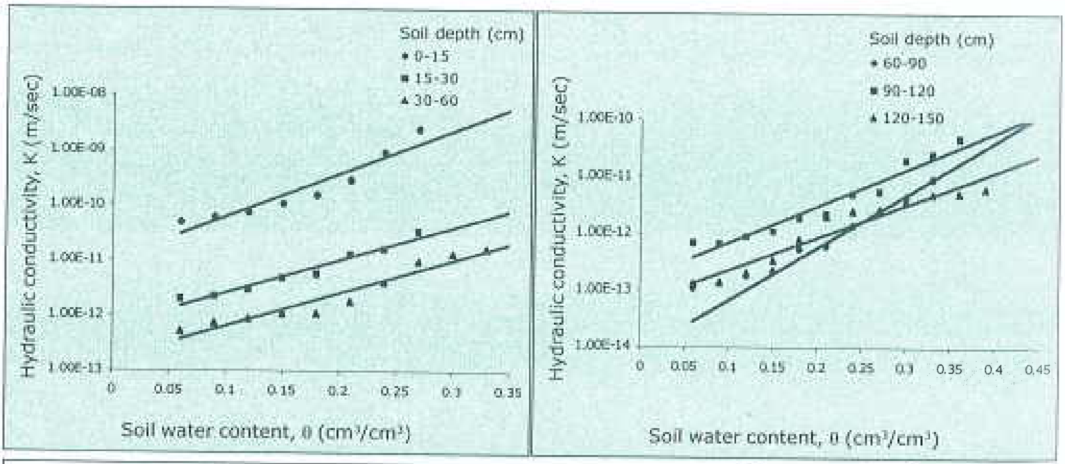

Fig.21c. Hydraulic conductivity as a function of water content in Typic Ustipsamment

where it varied from 0.399 to 0.578 cm^3 cm^{-3} and the lowest in Typic Ustipsamment, where it ranged from 0.107 to 0.238 cm^3 cm^{-3}. Similar trend of water retention were found in soils at 1.5 MPa. Highest available water content was found in Aeric Fluvaquent subgroup and the lowest in Typic Ustipsamment.

Data on penetrability (P), intrinsic penetrability (Pi), sorptivity (S), weighted mean diffusivity (D) and intrinsic weighted mean diffusivity (Di) of water in the soils are presented in Tables 22b to 24b. The penetrability values were found to be the highest in Typic Ustipsamment and the lowest in Aeric Fluvaquent. Intrinsic penetrability, sorpitivity, weighted mean diffusivity and intrinsic weighted mean diffusivity followed the same trend.

Data on water diffusivity and hydraulic conductivity in the soils as a function of water content are presented in Fig. 18b to 21b and 18c to 21c. Both the parameters varied widely with soil type. In general, values of water diffusivity and conductivity decreased as the water content decreased in all the subgroups but magnitude of change was different in different textured soils. Magnitude was very high in coarse textured soil like Typic Ustipsamment than in fine textured soil like Aeric Fluvaquent.

Table 26: Water storage capacity of the entisol profiles

Name of the subgroup	Profile water storage capacity (cm/m depth)	Category for profile water capacity
Aeric Fluvaquent	24.41	Very high
Typic Ustipsamment	7.67	Low
Typic Ustorthent	19.36	High
Lithic Ustorthent	21.13	Very high

Table 27: Erosion Index of the entisol profiles

Soil subgroup	Erosion index			
	Soil depth (cm)			Mean
	0- 15	15 -30	30 –150	
Aeric Fluvaquent	32.63	36.89	40.85	36.79
Typic Ustipsamment	45.86	34.92	28.96	36.58
Typic Ustorthent	32.27	24.47	21.12	25.95
Lithic Ustorthent	35.48	22.89	24.40	27.59
Mean	36.56	29.79	28.83	
C D (P=0.05) to compare	soil subgroup means:		1.55	
	soil depth means:		1.34	
	subgroup x depth:		1.10	

4.3.2 Profile water storage capacity: Profile water storage capacity of the entisols are presented in Table 26. Very high profile water storage capacity was observed in Aeric Fluvaquent and Lithic Ustorthent. The storage capacity was high in Typic Ustorthent and low in Typic Ustipsamment.

4.3.3 Erosion Index (EI):

EI of the entisols are presented in Table 27. In 0-15 cm soil depth, the highest EI of 45.86 was observed in Typic Ustipsamment and the lowest EI of 32.27 was in Typic Ustorthent. No significant difference was observed between Aeric Fluvaquent and Typic Ustorthent. In 15-30 cm and 30-150 cm soil depth, the highest EI of 36.89 and 40.85 respectively was observed in Aeric Fluvequent and the lowest EI of 22.89 and 21.12 respectively were observed in Lithic Ustorthent and Typic Ustorthent. Significantly higher value of mean EI was found for 0-15 cm soil depth.

4.3.4 Water management implications:

Application of organic materials like FYM and green manure will be necessary for Typic Ustipsamment and green manure with lime or lime sludge from paper mills for Typic Ustorthent to improve water use efficiency and productivity of these soils. Aeric Fluvaquent showed moderate salinity and low penetrability, intrinsic penetrability, sorptivity, weighted mean diffusivity and intrinsic weighted mean diffusivity. Although this subgroup has high moisture retention and available water capacity, it will be unable to supply sufficient water to plants because of their low transmission characteristics. Frequent supply of water to lower the suction is required for successful crop production in this soil subgroup. Proper selection of crops and monitoring of salt content in such soils are very important. Frequent medium to heavy irrigations will be effective to lower the salt content in root zone (Singh and Kundu, 2000). Adoption of proper soil and water conservation practices will be necessary to improve water use efficiency and crop productivity in Typic Ustipsamment, Typic Ustorthent and Lithic Ustorthent. While frequent light irrigations, preferably drip or sprinkler irrigation, will be useful to improve use efficiency of applied water in Typic Ustipsamment, medium irrigation applied at appropriate intervals will be effective in Typic Ustorthent. Lithic Ustorthent being shallow soils, shallow rooted crops and light to medium irrigation applied at appropriate interval will be effective.

In Aeric Fluvaquent and Lithic Ustorthent, cultivation of a second crop without irrigation will not be possible. In Typic Ustorthent, cultivation of a second crop without irrigation will be possible after rainy season provided it is sown immediately after the harvest of *kharif* crop or either as a *paira* cropping or with mulching. In Typic Ustipsamment, second crop is not possible without irrigation facilities. All subgroups need adoption of soil and water conservation techniques.

4.4 Soil Order: VERTISOL

These are uniform, thick (at least 50 cm), tropical black and other dark coloured, cracking mineral soils that have high content of clay (more than 30%) and mostly smectitic clay. These soils swell on wetting and shrink on drying, which induces development of wide, deep cracks and mostly angular blocky structure. The cracking, followed by filling of cracks and swelling, results in the development of gilgai microrelief. They are dominantly observed on lower topographic positions or on flat terrain at the foot of the gentle slopes. They are mostly neutral to alkaline in reaction and fertile with high base status.

In Orissa, there is only one suborder under vertisols, i.e. Ustert.

Ustert: In these soils, the cracks open and close more than once in a year. The cracks are open for 90 cumulative days or more but are closed for 60 consecutive days or more at a time when the soil temperature at lower depth is continuously above 8^{0}C.

Great group: There is only one great group, i.e. Chromustert.

Chromustert: These are the Usterts that have a chroma, moist of 1.5 or more than half of each pedon. Cracks remain open for more than 150 cumulative days. They are mostly on gentle slopes on which water does not stand.

Dominating subgroup:

1. Typic Chromustert

4.4.1 Physicochemical and hydrological characteristics: Physicochemical and hydrological characteristics of the Vertisol are presented in Table 28. Typic Chromustert was clay in texture with clay content ranging from 41.5 to 51.5 per cent. Bulk density varied from 1.36 to 1.44 Mgm^{-3}. The soil was free from any salt problem. pH$_2$ varied from 6.8 to 8.3. Subsoil was slightly alkaline in nature. Organic carbon content varied from 0.08 to 0.57 per cent. As the soil depth increased,

Table 28 (a) : Physico chemical characteristics of Typic Chromustert

Soil depth (cm)	Clay (%)	Silt (%)	Fine sand (%)	Coarse sand (%)	Textural class	Bulk density (Mg m^{-3})	EC$_2$ (dS/m)	pH$_2$	OC (%)	CaCO$_3$ (%)	CEC (me/100g)
0-15	41.5	24.7	12.0	21.8	c	1.36	0.23	6.8	0.57	2.0	21.75
15-30	44.4	25.5	14.7	15.4	c	1.37	0.20	7.3	0.45	1.6	31.32
30-60	45.9	23.2	12.5	18.4	c	1.39	0.26	7.7	0.36	1.5	30.15
60-90	47.5	25.5	11.4	15.6	c	1.40	0.35	7.9	0.30	2.2	29.58
90-120	48.5	25.8	9.2	16.5	c	1.42	0.39	8.0	0.18	2.0	29.58
120-150	51.5	26.2	6.6	15.7	c	1.44	0.44	8.3	0.08	3.2	34.15

Table 28 (b): Hydraulic characteristics of Typic Chromustert

Soil depth (cm)	Ks (cm/hr)	θs (cm^3/cm^3)	θ (cm^3/cm^3) at 0.033 MPa	θ(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)	P (m/√s)	Pi (√m)	S (m/√s)	D (m/s)	Di (m)
0-15	0.905	0.588	0.388	0.203	0.185	8.066×10^{-4}	9.447×10^{-5}	3.666×10^{-4}	1.336×10^{-7}	1.830×10^{-9}
15-30	0.284	0.607	0.382	0.201	0.181	7.853×10^{-4}	9.197×10^{-5}	3.356×10^{-4}	5.377×10^{-7}	7.366×10^{-9}
30-60	0.167	0.602	0.419	0.225	0.194	5.161×10^{-4}	6.044×10^{-5}	4.028×10^{-4}	2.097×10^{-7}	2.873×10^{-9}
60-90	0.149	0.661	0.465	0.241	0.224	2.476×10^{-4}	2.900×10^{-5}	2.166×10^{-4}	3.107×10^{-8}	4.257×10^{-10}
90-120	0.025	0.678	0.483	0.253	0.230	2.381×10^{-4}	2.789×10^{-5}	2.041×10^{-4}	3.844×10^{-8}	5.266×10^{-10}
120-150	0.021	0.680	0.492	0.271	0.221	2.352×10^{-4}	2.754×10^{-5}	1.568×10^{-4}	2.662×10^{-8}	3.647×10^{-10}

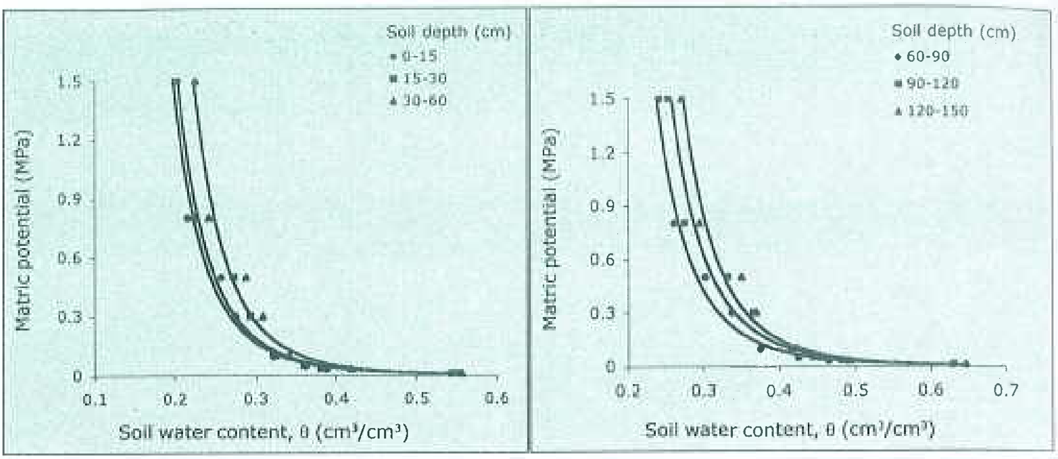

Fig.22a. Matric potential as a funtion of soil water content in Typic Chromustert

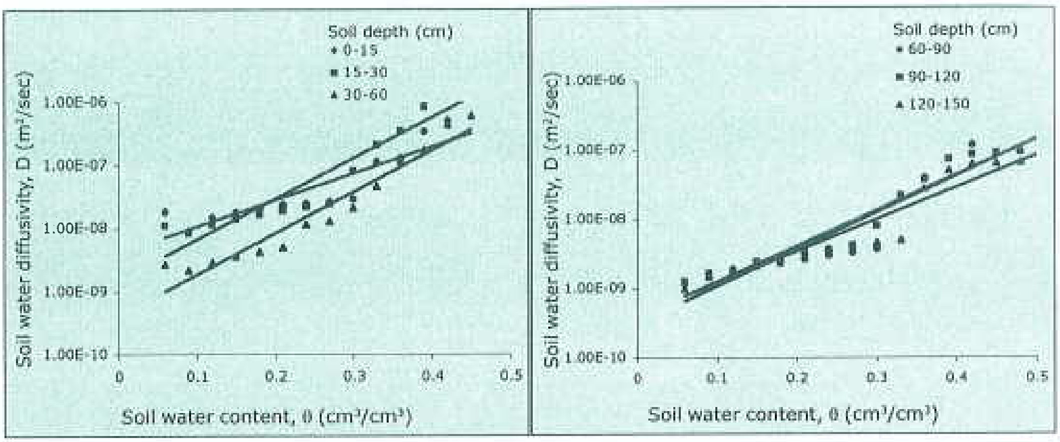

Fig.22b. Soil water diffusivity as a function of water content in Typic Chromustert

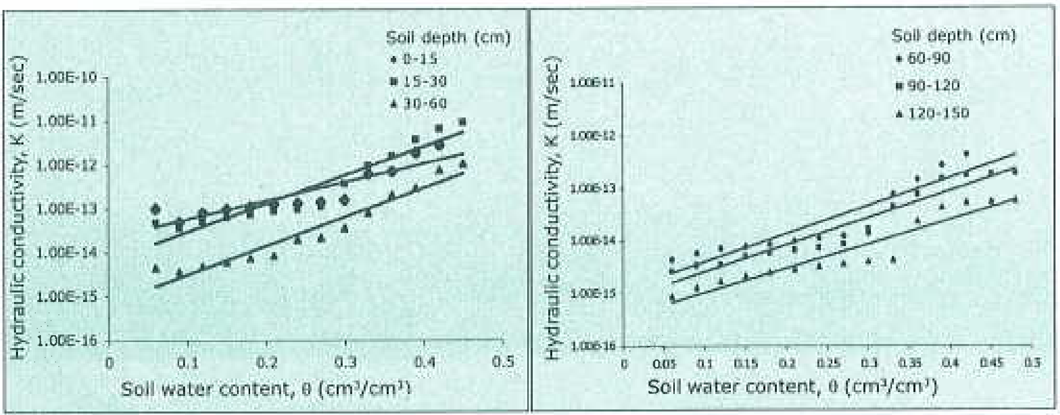

Fig.22c. Hydraulic conductivity as a function of water content in Typic Chromustert

OC content decreased. $CaCO_3$ content ranged from 1.5 to 3.2 per cent and CEC ranged from 21.75 to 34.15 me/100 g. Saturated hydraulic conductivity varied from 0.905 cm/hr in 0-15 cm soil layer to 0.021 cm/hr in 120-150 cm soil layer. Higher water retention at 0.033 and 1.5 MPa and available water content was observed in deeper soil layers. The highest values of penetrability (P), intrinsic penetrability (Pi), sorpitivity (s), weighted mean diffusivity (D) and intrinsic weighted mean diffusivity (Di) were observed in 0-15 cm soil depth in comparison to other soil depths. Data on water diffusivity and hydraulic conductivity in the soil as a function of water content is presented in Fig. 22b and 22c, respectively.

4.4.2 Profile water storage capacity : Profile water storage capacity in this subgroup was very high, it was measured at 20.33 cm m^{-1}

4.4.3 Erosion Index : Mean erosion index values for soils at 0-15,15-30 and 30-150 cm depths were found to be 13.42, 9.37 and 15.72, respectively.

4.4.4 Water management implications

Adoption of suitable management practices for *in situ* conservation of soil and water will be necessary to improve water use efficiency and crop productivity in this subgroup. The soils need to be ploughed at proper tilth. Water holding capacity of these soils is high but transmittivity is very low, hence plants suffer from drought even at moderate soil moisture status. Application of organic materials like rice straw, sawdust, molasses, etc. would improve soil aggregability and water movement in these soils. Medium to heavy irrigation applied at long intervals will be effective. Problem of water logging is more in this subgroup, hence proper drainage is essential.

5. PREDICTION OF WATER STORAGE CAPACITY OF THE SOIL PROFILES

Correlation studies were undertaken to identify important variables for establishing prediction equations of profile water storage capacity.

5.1 Correlation

Simple correlation coefficient (r) was worked out between sand, silt, clay, bulk density, organic carbon, calcium carbonate and cation exchange capacity and water retained at field capacity, wilting point and available water capacity. Values are presented in Table 29. The results revealed that water content at field capacity and wilting point had a close relationship with clay (r = 0.85** and 0.91**, respectively) and cation exchange capacity (r=0.81** and 0.29**, respectively). They were significantly but negatively associated with sand and bulk density indicating that with increase in value of either sand or bulk density or with decrease in magnitude of clay or silt or cation exchange capacity, water content, θ (cm^3cm^{-3}) of these soils at field capacity and wilting point, decreases. Coarse fraction (sand) has a close relationship with bulk density (r= 0.69**), whereas negative association exists between coarse fraction and finer fraction, i.e. silt (r=0.86**) and clay (r=0.88**) of these soils. Available water showed positive correlation with silt, clay, calcium carbonate and cation exchange capacity and negative correlation with sand and bulk density. These results are in good agreement with those of Patgiri *et al*. (1993), Yadav *et al*. (1995), Nagar *et al*. (1995) and Das and Dutta (1997).

Moisture retention at field capacity and wilting point, and available water in these soils were influenced by two sets of factors influencing in opposite direction (Table 29). While one set of factors, viz. silt, clay, organic carbon, calcium carbonate and cation exchange capacity influenced positively, the other set of factors, viz. sand and bulk density influenced negatively. Consequently, the available water content was also influenced by the same set of factors and in a similar manner.

Table 29: Simple correlation coefficients

	Sand (%)	Silt (%)	Clay (%)	Bulk density (Mg m^{-3})	OC (%)	$CaCO_3$ (%)	CEC (me/100 g)	θ, at field capacity (cm^3 cm^{-3})	θ, at wilting point (cm^3 cm^{-3})	Available water capacity (cm^3 cm^{-3})
Sand (%)	1.00									
Silt (%)	-0.86**	1.00								
Clay (%)	-0.88**	0.51**	1.00							
Bulk density (Mg m^{-3})	0.69**	-0.66**	-0.54**	1.00						
OC (%)	-0.06	0.13	-0.01	-0.45**	1.00					
$CaCO_3$ (%)	-0.54**	0.43**	0.50**	-0.55**	0.12	1.00				
CEC (me/100 g)	-0.72**	0.49**	0.76**	-0.57**	0.10	0.43**	1.00			
θ, at field capacity (cm^3 cm^{-3})	-0.89**	0.67**	0.85**	-0.63**	0.06	0.55**	0.81**	1.00		
θ,at wilting point (cm^3 cm^{-3})	-0.84**	0.53**	0.91**	-0.55**	0.03	0.55**	0.79**	0.92**	1.00	
Available water capacity (cm^3cm^{-3})	-0.78**	0.73**	0.64**	-0.61**	0.14	0.47**	0.68**	0.91**	0.67**	1.00

** significant at 1 per cent.

Table 30: Linear regression co-efficients of various equations fitted to field capacity, wilting point and available water as a function of soil physicochemical parameters

a	B							R^2
	Sand (%)	Silt (%)	Clay (%)	Bulk density (Mg m^{-3})	OC (%)	CaCO3 (%)	CEC (me/100 g)	
For field capacity								
1.557	-0.016	-0.013	-0.011	0.040	-0.003	0.016	0.003	0.853
-5.544	0.057	0.061	0.064	-0.108	-0.001	0.015		0.818
-9.965	0.103	0.106	0.110	-0.202	-0.006			0.813
-9.9446	0.098	0.101	0.104	-0.186				0.813
-4.320	0.044	0.047	0.050					0.810
0.708	-0.007	-0.003						0.810
0.577	-0.005							0.788
0.522	-0.005	-0.001					0.003	0.840
For wilting point								
9.82	-0.099	-0.099	-0.095	0.042	-0.016	0.011	0.001	0.870
6.899	-0.069	-0.069	-0.064	-0.019	-0.014	0.011		0.851
3.701	-0.036	-0.035	-0.031	-0.087	-0.018			0.843
5.316	-0.053	-0.052	-0.048	-0.038				0.842
6.369	-0.064	-0.063	-0.059					0.842
0.472	-0.005	-0.004						0.841
0.289	-0.003							0.704
0.399	-0.004	-0.004					0.001	0.859
For available water								
-8.265	0.083	0.086	0.084	-0.002	0.012	0.005	0.002	0.678
-12.443	0.126	0.129	0.128	-0.089	0.014	0.004		0.636
-13.666	0.139	0.142	0.141	-0.115	0.012			0.634
-14.762	0.150	0.153	0.152	-0.148				0.634
-10.689	0.107	0.111	0.109					0.627
0.237	-0.002	0.001						0.625
0.288	-0.003							0.613
0.123	-0.001	0.002					0.002	0.673

5.2 Regression

Stepwise regression analysis was carried out to scan the effectiveness of the influence of variables, viz. sand, silt, clay, bulk density, organic carbon, calcium carbonate and cation exchange capacity on water content at field capacity and wilting point, and on available water. Regression coefficients and R^2 values are given in Table 30. All the variables put together accounted for a variation of 85.3, 87.0 and 67.8 per cent for the water retained at field capacity, wilting point and available water, respectively. Sand, silt, clay, bulk density, organic carbon and calcium carbonate accounted for 81.8 per cent variation in water retention at field capacity; sand, silt and cation exchange capacity together accounted for 84.0 per cent variation, and sand and silt together accounted for 81 per cent variation. In case of wilting point: sand, silt, clay, bulk density, organic carbon and calcium carbonate together were responsible for 85.1 per cent variation; sand, silt and cation exchange capacity accounted for 85.9 per cent variation; and sand and silt together accounted for R^2 values of 84.2 per cent. Inclusion of cation exchange capacity in the model improved the prediction values of retention both at field capacity as well as at wilting point. Similar types of observations were also made by Singh *et al*. (1988 and 1992) for alluvial soils.

For prediction of available soil water: sand, silt and cation exchange capacity accounted for 67.3 per cent variation; sand, silt, clay, bulk density, organic carbon and calcium carbonate contributed to only 63.6 per cent; and sand and silt together accounted for 62.5 per cent variation. Hence, available water can not be predicted as accurately as water content at field capacity and wilting point. It was better to estimate available water using the predicted values of field capacity and wilting point.

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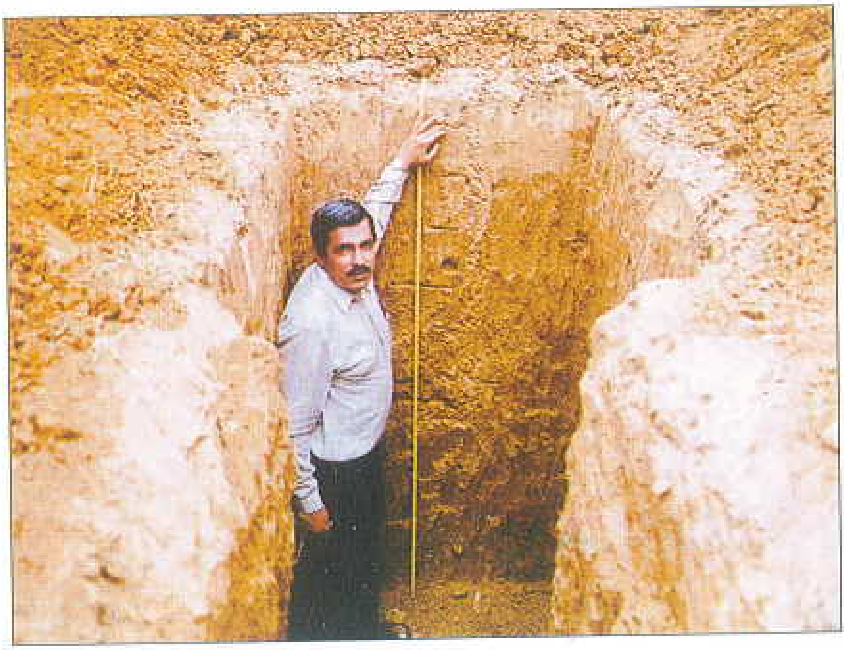

View of a soil profile