SURVEY AND CHARACTERISATION OF SOILS OF R.R.T.T.S. BHAWANIPATNA IN THE WESTERN UNDULATING AGRO-CLIMATIC ZONE OF ORISSA

A THESIS SUBMITTED TO
THE ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, BHUBANESWAR
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE

(AGRICULTURAL CHEMISTRY, SOIL SCIENCE AND BIOCHEMISTRY)

By

Ramakanta Parida

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BHUBANESWAR, ORISSA

2000

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DEDICATED

TO

THE IMMORTAL SOUL

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CERTIFICATE

This is to certify that the thesis entitled **"Survey and Characterisation of soils of RRTTS, Bhawanipatna in the Western Undulating Agro-climatic Zone of Orissa"** submited in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (Agricultural Chemistry, Soil Science and Biochemistry)** to the Orissa University of Agriculture and Technology, Bhubaneswar is a faithful record of bonafide research work carried out by **Sri Ramakanta Parida**,under my guidance and supervision.No part of this thesis has been presented in any form for any other degree or diploma. All posssible help and sources of information availed during the course of thesis investigation have been duly acknowledged.

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APPROVAL SHEET

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ACKNOWLEDGEMENT

I avail this opportunity to express my deep sense of gratitude, reverence and indebtedness to Dr.G.C.Sahu, Associate Professor, Department of Agricultural Chemistry, Soil science and Biochemistry, college of Agriculture, O.U.A.T, Bhubaneswar for his incomparable guidance, constant supervision, constructive criticism, whole hearted cooperation and incessant encourgement in carrying out this research work, as well as preparation of manuscript.

I convey my deep sense of honour and gratitude to Dr.D.Sahu, Professor and Head, Department of Agricultural Chemistry, Soil Science and Biochemistry, O.U.A.T. for providing me all laboratory facilities to carry out my research work.

I extend my deep sense of gratitude to Dr. N.C. Sahoo, Assoc. Prof., Plant Physiology and Mr. N.Patro, Assoc. Prof. Agronomy who acted as members of the advisory committee and rendered whole hearted co-operation during the period of investigation.

I am very much grateful to Dr. B.B.Bhol, Associate Director of Research, RRTTS, Bhawanipatna for providing all facilities during digging of profile pits, study and collection of soil samples and assisting in procurement of preliminary information.

I do express heartfelt special gratefulness to my honourable teachers Dr. S.K.Sahu, Dr. S.K.Pattnayak, Dr. K.K.Rout, Dr. N.K.Pradhan, Mr. A.K.Dash and thanks to Mr. M.K.Jena, Mr. R.K.Nayak, Mr. D.N.Kar, Mr. P. K.Samanta and Mr. N. Das of the Dept. of Agriculture chemistry, Soil Science and Bio-chemistry, O.U.A.T. for their constructive criticism and help rendered during the entire course of my work.

I also owe heartful gratefulness to the Director, Soil Conservation, Orissa Bhubaneswar for allowing me for M.Sc.(Ag.) study at O.U.A.T.

Words run short to deliver my irreversible thanks to Rupak, Satya, Munmun, Madhusmita, Kajal, Badhulika, Bandita and Lata for their help at the time of need.

I am also thankful to CCAD for neatly typing out the manuscript .

I owe my success to my Kaka and Sanbou, Buly, Lily and Mily whose inspiration and cooperation only could bring me to this stage of success.

With heartful love and affection, I express my indebtedness of my wife, Baby, my son, Subham, who have sacrificed a lot for the success of this research work.

Last but not the least, I bow down my head before my most revered godly parents whose blessings, love and dedication brought me to achieve this cherished goal.

Bhubaneswar,
Dated. 2000

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RAMAKANTA PARIDA

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Title of the Thesis	:	Survey and Characterisation of Soils of RRTTS, Bhawanipatna in the Western Undulating Agroclimatic Zone of Orissa.
Author	:	Ramakanta Parida
Major advisor and Designation	:	Dr. G. C. Sahu, Associate Professor, Department of Agricultural Chemistry, Soil Science and Biochemistry.
Degree for which	:	Master of Science in Agriculture, (Agricultural Chemistry, Soil Science and Biochemistry).
Year of Submission	:	2000

ABSTRACT

Five Pedons representing the different physiographic situations of Regional Research and Technology Transfer Station, (RRTTS), Bhawanipatna under Western Undulating Zone of Orissa situated on 19.58^0 N latitude and 83.12^{0}E longitude under hot and moist subhumid climate with 1354 mm average annual rainfall were morphologically studied, characterised and classified. The soil colours are dark grey brown to pale brown. The soils are very deep and cracks of 2-3 cm wide extend continuously upto more than 1 m. In the subsurface horizons, slickensides, wedge shaped aggregates, Fe, Mn concretions, and lime concretions are observed.

The soils of the mid upland situation is sandyloam on the surface, which grades to clay loam downward. But the soils in the mid lowland situations are clay to clay loam and the subsurface horizons are clayey throughout. The surface soils are moderately well drained, whereas, the subsoils are imperfectly to poorly drained.

Almost alkaline reaction persists throughout the pedons , but the value of E.C. is low. Organic matter content is medium on the surface and the value decreases downward. The value of C.E.C. is comparatively high and it increases down the depth, having a significant correlation with clay (r = 0.989**). Presence of free $CaCO_3$ is encountered and the value increases down the depth. The exchange complex is dominated by Ca^{2+}, followed by Mg^{2+}, Na^+ and K^+. The soils are base rich with percentage base saturation of 88 to 98. From much higher value of CEC/clay percentage (65 to 75), smectitic nature of clay minerals are inferred.

Vertical distribution of available N is almost low in all the horizons with a gradual decreased value from the surface. So also the available P distribution is almost medium and the value decreases from the surface. On the other hand, the available K is medium to high and the soils are sufficiently rich in sulphur. The fertility status of composite surface samples indicated N to be low, P is high and K is medium.

Coefficient of correlation studies of some soil properties with micronutrients indicated that clay and pH are significantly correlated with D.T.P.A. extractable Zn, Fe and Mn. Organic carbon is positively correlated with Cu and Fe. $CaCO_3$ is negatively correlated with Zn, Mn and Fe.

Soils were classified as per Soil Taxonomy (1975). The pedons situated in the mid low-lands are *Typic/Chromic Haplusterts* and soils of the mid medium lands are *Vertic Haplustepts.*

Different cropping systems and improved soil, water, crop management systems for obtaining sustained and better yield in the research station has been suggested.

CHAPTER - I

INTRODUCTION

CHAPTER - I

INTRODUCTION

Soil is regarded as the most important and vital natural resource for the mankind. A correct assessment of the potentialities of this resource is, therefore, absolutely essential in planning out any developmental programme. Since Liebig's(1870) findings of major plant nutrients, soil studies draw the attention of scientists as a store house of these nutrients.

The need for optimum use of land has been much greater now-a-days, with rapid population growth and urban expansion. The increasing demand for intensification of existing cultivation, especially in areas with less favourable conditions leads towards a new equillibrium among human factors, socio-economic conditions and the factors of physical environment. Moreover, in industrialized agriculture system, the trend of location specific specialisation in crop production is gaining momentum in relation to traditional agriculture. In the coming millennium , we will have to produce more food and other agricultural commodities under conditions of diminishing per capita aerable land and irrigation water resources and expanding biotic and abiotic stresses. (Swaminathan, 1999). Population of India is likely to reach 1.4 billion by 2025 AD when food grain requirement would be 300 million tonnes; about one and half times more than the present production. Thus food production must keep pace with increasing population.

In order to get over these problems, a knowledge of the kind and extent of distribution of soils is required to analyse the problems, productivity and potential. Soil survey and characterisation and putting it into an appropriate taxonomic class helps to provide a base for research on soil, water and crop management, their response to various inputs under varied agro-ecological situations. It envisages to find out the cause of the problem and to develop possible methodology in bringing the handicapped soils under plough. Thus soil survey and characterisation is imperative for the planners and researchers to have better land use planning for sustainable agricultural production in order to safeguard the present and future generations.

Out of total geographical area of 15.57 m ha. in Orissa Vertisols (black soils) occupy an area of 0.86 m ha. (Sarkar *et al.,* 1998) . These soils pose problems for normal crop husbandry because of constraints in climatic components and soil factors. Soil factors that are dominant constraints to normal use are; unfavourable (clayey) texture and tilth, high bulk density, wide and deep shrinkage cracks, saturated slow hydraulic conductivity in the subsoil, self swallowing nature and severe erosion on upland situation. Crop diversification is limited in these soils. The soils need to be ploughed at the proper tilth, because on drying, the soils become very hard to plough and on excess moisture the soil becomes very sticky and plastic. These soils are prone to drought because of low availability of water although the water holding capacity is high. Soil reaction is moderately alkaline for which P and Zn deficiencies are observed and NH_3 volatization is higher. Fe^{2+} ion present in higher quantities in the exchange

complex, interferes with the absorption of other cations. Although the capacity of K is high, the potential K status is low. Organic matter content is also low for which management of these soil is difficult.

RRTTS, Bhawanipatna represents black soils in the western undulating zone. Soil survey and characterisation of this research station has not been made so far.

Thus in the present context, soils from RRTTS, Bhawanipatna is being taken for their characterisation and classification. RRTTS, Bhawanipatna which is the one among the eight research stations under O.U.A.T., Bhubaneswar caters to the technological needs of the entire western undulating zone of Orissa.

Objective of study :

The study comprises of the following operations, involving,

i) To survey the area in detail and select profile sites as per physiography.

ii) To study morphological characteristics of soil profiles and collection of soil samples.

iii) To study the physical and chemical properties of soil profiles and adjoining surface samples.

iv) To analyse the available nutrient (macro and micro) status of the soil.

v) To prepare a soil fertility map of the Research Station.

vi) To classify the soils as per Soil Taxonomy.

HAPTER - II

REVIEW OF LITERATURE

CHAPTER - II

REVIEW OF LITERATURE

The literature pertaining to the present investigation has been reviewed under the following sections.

A. Morphological and Physical Characteristics

B. Chemical Characteristics

C. Physiography and land form

D. Mineralogy of soil.

E. Genesis of black soil

F. Classification

A. Morphological and physical characteristics:

Soil morphology is the description of the soil body, its appearance, features and general characteristics as expressed in profile of a soil. The morphology of the soils is expressed by number, kinds and arrangement of different horizons at their observable and measurable characteristics. These are colour, texture, structure, consistence, cutans ,nodules, concretions, voids, roots and any other special features, boundary characteristics and horizon continuity. The skill with which the soil properties are recognised and recorded determines the quality of the resulting soil description, which serves as the basis of the classification of soils into definite categories (Soil Survey Staff, 1995).

Bourne and Whiteside (1962) in their study on morphology and pedogenesis of a medial chernozem developed on loess, have described the texture to be clay loam. Its A-horizon is dark gray brown and granular, B-horizon is dark grayish brown and prismatic blocky and C-horizon is calcareous, pale brown, massive, silt loam.

Black soils of India are clayey(mainly montmorillonitic) possess a blocky structure, are plastic and sticky when wet and hard when dry, contain very little organic matter (Roy and Barde,1962).

Gowaikar and Barde (1964) have studied some black soils of Amravati district of Vidarva and found that the soils are deep, well drained ,dark to brown colour with blocky structure. Lime kankers are observed in abundance in the profile.

Barde *et al.* (1966) described some black profiles of Bhandar, Maharastra. These soils are dark to very dark gray brown throughout the profile, texture varies from silty clay to clay, structure, blocky with dark coloured ferrugenious concretion throughout . Lime concretion are also seen with varying proportions in the profile. pH of the soil is neutral to slightly alkaline. Soils are very hard when dry and crack heavily and the permeability is slow to very slow.

Black soil profiles developed on basaltic parent material of Bombay Deccan, are very dark grayish brown, clayey, angular blocky, hard when dry and calcareous. Cracks are wide ,vertical and horizontal.(Tamhane & Karale, 1967).

Seven soil pedons of the catenary sequence from Dadra and Nagar Haveli was studied by Challa and Gaikwad (1986). The soils of flat topped hills,

foot hill slopes and flood plains had the dark reddish brown colour and medium to slightly acidic pH (5.6 to 6.4) whereas, soils on piedmont plain and food plain (Dapada) have dark greyish brown to dark brown colour and slightly acid to moderately alkaline pH (5.8-7.9). The piedmont plain soils with powdery lime were mixed with soil matrix of flood plain (Dapada) and other piedmont soils. Rest of the soils were non-calcareous. The soils could be classified into Entosols, Inceptisols and Vertisols in the sequence.

Morphology of four black soil pedons under Bargi irrigation project in Madhya Pradesh (Kaushal *et al.,* 1986) , contain a uniform dark brown clay solum, with intersecting slickensides and parallelepiped aggregates. The soils are neutral to alkaline with the particle size class of fine to very fine.

Venugopal *et al.* (1989) studied a paleosol (buried) developed on pre-Cambrian biotic genesis in an acidic parent material under humid climate and indicated typical morphological and micromorphological characteristics of a shrink and swell soil.

Some physical properties of vertisols derived from different parent materials of N. Karnataka indicated that water holding capacity, available water capacity, plasticity index, specific surface area and total porosity were higher in soils derived from chlorite schist (Hirekurubar *et al.* 1991). Their physical properties were lower in soils developed from limestone. Low bulk density microporosity and steady state infiltration rate were higher.

Genesis and morphology of vertisols developed on different parent materials(Subbaiah & Manickam, 1992) indicated that parent material rich in

$CaCO_3$ gave rise to shallow profile. Soil profiles derived from granite were not calcareous. The size and abundance of calcium carbonate concretion increased with depth. Pedons developed on shales and charnockite had shown granular and crumb structure while pedons developed on granite-gneiss, granite and limestone had shown subangular blocky structure in the surface horizon.

Paramasivam (1995) studied 5 typical soil profiles of vertisols and stated that infiltration rate and hydraulic conductivity were low in *Typic Chromusterts* (black clay loam soil).

Mermut *et al.* (1996) describing the macro and micro morphological characteristics stated that morphology is the most important factor used to differentiate vertisol from other soil orders. Similar observation of William *et al.* (1996) in the field morphology of vertisols were made in which he emphasised on gilgai microlows, microhighs, slickenslides etc. for identifying vertisols.

Bhattacharjee *et al.* (1997) reported vertisol profiles of Umbraj, Otur and Linga soil series of Maharashtra, by wide shrinkage cracks, gilgai surface micro relief, an angular blocky structural profile with shiny pressure faces on the peds.

Padole (1997) studied morphology of vertisol of Central Demonstration Farm, Akola, and found that pedons are shallow to deep to very deep. Soil textures were clay to clay loam, with moderately well drained conditions and calcareous.

Anitha *et al.* (1998) studied the morphology of black soils of Gurazala Mandal in Guntur district of Andhra Pradesh and reported that the presence of

surface cracks, slickenslides, fine texture, gilgai micro relief and lime concretion. The soils were deep to very deep.

B. Chemical characteristics :

Chemical properties of soil include soil reaction (pH), electrical conductivity (E.C.), macro-and micro nutrient status, cation exchange capacity (C.E.C.), free calcium carbonate, etc.

A detail study of three vertisols formed under semiarid climate on Deccan trap, lime stone and gneiss was conducted by Dasog and Hadimani (1980). The soils are developed under similar set of factors of soil formation except parent rock. However, the influence of parent rock is subdued in the solum as evident from the soil properties. The soils were clayey in texture, have more than 15% exchangeable sodium and are highly calcareous. They contain less free iron and Ca-P as the dominant P-fraction, indicating mild intensity of weathering.

Physico-chemical characteristics of coastal and inland black soils of south Gujrat(Kaswala & Despande, 1983) showed that these are fine textured, low in organic carbon, but high in C.E.C. and is positively correlated with clay content. The pH of inland soils is neutral to alkaline whereas, that of coastal soils were alkaline. The dominant exchangeable cation was calcium in the former and sodium in the latter. Comparatively more calcium carbonate and organic matter are observed in coastal soils throughout the profile. The electrical conductivity of inland soils is quite low, while it was very high in coastal ones.

Shanwal *et al.* (1988) studied the soils of four pedons of Haryana Agricultural University farm, Hissar, Haryana. Although clay increased in the

subsurface horzons suggesting clay illuviation, no clay cultans were noticed on ped faces. There was regular increase of $CaCO_3$ in two soil profiles. The soils were low to medium and medium to high in available P and K content respectively. The soils were classified as **Ustocrepts**.

Kitijah Kosayodom (1986) reported chemical properties of vertisol in Lopburi province (Thailand) and found that they had medium fertility status . Organic matter content, available phosphorus and potassium in these soils were high in surface soils and decreased with depth. Their C.E.C. ranged from high to very high depending mainly on their exchangeable calcium and magnesium content. They had high base saturation percentages.

The potassium status of vertisols and associated soils in a toposequence showed that, the surface soils had high water soluble potassium which in most of the cases, decreased along the depth of the profile. The available potassium was rated high, considering the limit of available potassium as 300 kg/ha (Sharma & Dubey, 1988).

Viswanath and Doddamani (1991) studied distribution of phosphorus fraction in some vertisols of Malaprabha command area of Karnataka and found that available phosphorus decreased with depth. The calcium phosphate was the dominant mineral form of phosphorus in the soils studied.

Tiwari and Bansal (1992) studied the vertical distribution of potassium in some vertisols profiles of northern Madhya Pradesh and found that water-soluble potassium decreased with depth. Lime content was negatively correlated with potassium .

Padmaja *et al.* (1993) studied the status and distribution of sulphur in vertisols of Nalgonda and Mahaboobnagar district of Andhra Pradesh and found that the inorganic sulphate - sulphur content extracted with 0.15% calcium chloride ranged from 8-19 mg/kg. In most cases, the value increased with depth. The sulphur has no significant correlation with pH, E.C., calcium carbonate, clay and organic carbon content of soils.

Eightfour pedons representing soils from Entisols, Inceptisols and Vertisols of Maharastra (Satyavathi *et al.* 1994) showed that cation exchange capacity (C.E.C.) of the soils was closely related with content of clay followed by that of silt and organic matter. Multiple regression equation relating clay, silt and organic matter content with C.E.C. of the soils could be used precisely for predicting the C.E.C. of the soils having less than 40% clay.

Highest level of available DTPA extractable Zn, Cu, Fe and Mn are observed in the surface layers of Tal land soils(Tiwari & Mishra, 1990). In most of the cases, DTPA Zn and Mn decreased with depth, whereas , DTPA ,Cu and Fe are fairly uniform in distribution. The available Zn was found to be negatively correlated with pH but positively correlated with clay and organic carbon. Mn was also found to be positively correlated with clay and organic carbon. However, Cu and Fe were both found to be positively correlated with pH, clay and organic carbon.

Singh and Sekhar (1991) reported DTPA extractable micronutrient cations in 20 vertisol soil series of India and found that deficiency of Zn is expected in 6

soil series and adequate in 14 series, taking 0.6 ppm Zn as the threshold value. Fe, Cu, Mn were found to be adequate in soils of each of 20 soil series.

There was no regular trend in the distribution of DTPA , Zn, Cu, Fe and Mn in the vertisol profiles of Bihar(Diwankar & Singh, 1992) but there is indication towards irregular decrease down the depth.

The status of DTPA Zn in vertisols (Sharma & Lal, 1992) is influenced by factors like pH, EC, organic carbon, clay content, available potassium and phosphorus. Considering a critical level of 0.6 ppm, 20% of the soil samples were found to be deficient and 80% being sufficient with a mean of 1.1 ppm.

The study of distribution of micronutrient in major vertisols of lower Bhawani Project Command area (Paramasivam & Gopalswamy ,1994) revealed that available Zn, Fe, and Cu decreased with depth in typic chromustert. All the micronutrients are in sufficient level except Zn. All the micronutrients are closely related with organic carbon and clay.

DTPA extractable Zn, Cu, Fe and Mn are associated with parent material, organic carbon, clay content and pH and the contents decreased with depth in vertisols (Diwankar & Singh ,1995).

Murthy *et al.* (1997) reported DTPA Zn, Cu, Fe and Mn from 5 profiles of vertisols from different parent material are adequately supplied . But considering 0.6 mg/kg as critical level for deficiency of Zn, the soils developed on basalt are rich in Zn, whereas soils developed on grey shale and lime stone are deficient in Zn.

The data collected from vertisols of Solapur, Nagpur and Bhopal (Prasad & Gajbhiye, 1999) indicated that DTPA extractable Zn in these soils ranged from 0.14 to 0.63 mg/kg . The DTPA Cu ranged from 1.3 to 4.6 mg/kg; that of Fe from 0.6 to 10.4 mg/kg and Mn from 3.0 to 15.1 mg/kg. Zn and Mn show a decreasing trend, while Cu shows an almost uniform trend down the depth. Surface layer of all pedons have low content of Fe than the sub-surface layers.

c. Physiography and land form :

Physiography and land use relate to land use classification requiring the uses of land in accordance with its capability and limitations. Land form is a broader term which includes among its characteristics, not only soil but other physical attributes such as existing plant cover, inherent soil characteristics and landscape features like slope, degree of erosion that limits the safe and productive use of soil. Some important research finding regarding topography and land form by different workers have been presented below.

The term toposequence was introduced by Jenny (1941). The topography and land form affect the air and water movement in soil by their effect on drainage, run off and erosion to a great extent.

Yadav *et al.* (1977) studied catenary relationship existing among the soils of the lower Vidhyan Plateau in Utter Pradesh. They selected two toposequences one developed on a sand stone formation and the other on a limestone / shale complex with profile each on the upland, terrace and valley low land. Clear catenary relationships were apparent. The soils of the upland and terraces were classfied as Alfisols and those of the lowland as Inceptisols.

Saxena and Singh (1982) studied eight soil groups occurring in semiarid to humid agroclimatic regions of Rajasthan and observed that though parent material seemed to exert a major influence, a gradient in degree of profile development was observed. Soils of subhumid region generally showed a higher degree of weathering and formation of secondary products. Different soils can be arranged in order of increasing intensity of pedogenic development as (I) In semi arid region :- Alluvial soils of recent origin < non-classic brown< gray brown < brown soil (ii) In subhumid to humid region : hill soils< yellowish brown < red loam < deep medium black soil.

Soils of Andaman and Nicober Island were studied by Singh *et al.* (1988) and found that, depending on the physiographic position soils exhibited the characteristics of orders like Entisols, Inceptisols and Alfisols.

Morphology and other characteristics of Nimkheda soil in Jabalpur , Madhya Pradesh were studied in relation to topography. (Prasad *et al.,* 1989). Taxonomically, these soils were classified into Alfisols, Entisols, Inceptisols, Mollisols and Vertisols. Entisols were the dominant soils of hillocks and convex erosional slopes. Alfisols were the next dominant soils. Mollisol occurred in moderately steep slope whereas, vertisol was in very gently topography.

Deshmukh and Bapat (1993) characterised and classified the soils in Raisen district of Madhya Pradesh in relation to different parent rocks and land forms. Good physiography soil relationship has been established. Soils at higher elevations were less developed and have low pH, calcium carbonate, clay content, C.E.C., exchangeable metalic cations than the soils in lower elevations.

Difference in soil development is due to difference on parent material, vegetation and elevation. Taxonomically these soils have been classified as vertisols, Inceptisols and Entisols.

Shyampura *et al.* (1994) studied five pedons of different physiographic regions in Durgapur district of Rajastan belong ing to Entisol, Inceptisol and Alfisol to establish the relationship of soil physiography. The soils on very steeply sloping side slopes are shallow, excessively drained and coarser in nature, whereas, the soils of gently sloping pediment and undulating plains are deep, finer in texture and have better structural development. Clay cutans and fine clay to total clay ratio provided evidence of argillic horzions in the soils on very gently sloping and vearly level plains. Sand/slit ratio (>0.2mm) suggest lithological discontinuity between overlying Ap and underlying Bt horizon. The depth distribution of Al_2O_3 , Fe_2O_3 and clay provided confirmity evidence of clay illuviation. The decreasing trend of fine sand total sand, C.E.C./clay, Al_2O_3/Fe_2O_3, molar ratio indicated that the soils on the stable land scape are more weathered compared to other soils on undulating topography.

D. Mineralogy of soil :

Primary minerals of sand and silt plays a definite role in the formation of mineral in clay fraction. The extent of decomposition and disintegration of the mineral depend on its stability. Clay fraction plays an important role in physico-chemical properties of soil. Thus, the literature pertaining to mineralogy of vertisol reviewed under this section is presented below under two subsections; mineralogy of sand fractions and mineralogy of clay fractions.

The quantitative mineralogical make up of clay fraction of coastal and inland soil series of black soils of South Gujrat (Kaswala & Deshpande, 1983) is dominated by smectite whereas quartz and feldspar are present in silt fraction. Vermiculite, mica, kaolinite and allophane are present in both the fractions in small variable amount. Coastal clays and silts are more micaceous than inland ones.

The mineralogical properties of 3 pedons of Bodali, Jabalpur and Kabilpur series consisting of vertisol are mostly smectite (58.2 to 65.4%) in the clays, followed by vermiculite (8.3 to 12.7%). (Kaswala & Deshpande, 1986).

The mineralogical composition of vertisols in Lop Buri Province (Thailand) studied by Kitdjah-Kosayodom (1986) indicated that silt fraction of these soils is composed mainly of quartz in high to very high amount. Feldspar is also present in small quantities. Kaolinite, quartz, feldspar in small quantities are observed in clay fractions of these soils.

Sahu *et al.* (1990) studied the clay mineralogy of two vertisol profiles in Orissa, developed under different physiographic units and clay minerals were characterised using x-ray diffraction, elemental chemical analysis, surface area, Y-value and potentiometric titrations. Montmorillonite group was found to be dominant mineral in the clay fraction in these soils. Illite and Kaolinite group of clay minerals were found in smaller amount.

The clay mineralogy of vertisols of the Tal land soil series developed on alluvium derived from rocks like granite-gneiss, mica-schist, quartzite seem to be geogenic and pedogenic (Diwankar & Singh, 1992), The formation of smectite

appears to be under basic environment, impeded drainage and waterlogged condition for a limited period. Mica is found to be derived from micaceous parent material.

Black soils developed on dolerite and basalt in low lying areas of Rajmahal trap (Bihar) contain clay minarology of multicomponent interstratified systems involving smectite-vermiculite- mica and possibly kaolinite layers. The chemical composition together with C.E.C. suggest the occurrence of minerals of expanding type. (Tiwari & Mishra, 1993).In another minerological study of the fine sand fraction of vertisols of Bihar (Diwankar & Singh, 1995) showed the presence of light mineral (feldspar, quartz, and mica) and heavy minerals (garnet and tourmaline) in sedentary soils. Smectite predominated in all vertisols with some amount of kaolinite and illite.

Clay mineralogy of some vertisols of Karnataka showed that smectite is the dominant clay mineral, followed by mica and kaolinite. (Manjaiah & Ghosh, 1995) .

Clay mineralogy of some vertisol soil series of Maharastra (Pharande & Sonar, 1997) developed on basalt/basaltic alluvium showed that smectite is the most dominant phyllosilicate in fine clays (more than 90%) with small proportion (less that 10%) of kaolinite.

Sand mineralogy of some vertisols of Trans Yamuna plain in Uttar Pradesh are found to consist of quartz, orthoclase, plagioclase feldspar and muscovite in order of their abundance.(Walia & Rao, 1997),

Mineral composition of clay samples collected from soils of Maharastra indicates that the soils are dominated by smectite, though vermiculite, chlorite, mica, kaolinite, and quartz are also present.(Padole, 1997).

E. Genesis of black soil :

The genesis of soil covers two distinct phases, the first phase consisting of the evolution and accumulation of soil material through weathering agencies and the second phase consisting of the development of soil profiles. The two processes work more or less simultaneously in nature. These processes are governed by the action of various soil forming factors. The five important soil forming factors as postulated by Jenney (1941) are climate, parent material, topography, organism and time. Dokuchaiv (1879) in Russia and Hilgard (1893) in America were the first two scientists to recognise the importance of soil factors in soil genesis.

Soil formation as affected by topography and time was studied by Abtahi (1980) in highly calcareous parent materials under semiarid conditions of Southern Iran. Slightly saline, coarse textured soils of higher elevations and high salinity, fine textured soils at lower elevations were classified as Inceptisols and Aridisols respectively.

The soils formed under semiarid climate on Deccan trap, limestone and gneiss are found to develop under similar set of factors of soil formation, except parent rocks. However, the influence of parent rock is subdued in the solum indicating mild intensity of weathering.(Dasog & Hadimani, 1980)

The genesis of the vertisol in semiarid climate and moderate rainfall reveal that parent materials rich in calcium carbonate give rise to shallow profiles. Soil profiles derived from granites are not calcareous.(Subbaiah & Manickam, 1992),

Six typical pedons representing basalts and basaltic alluvium in Rajasthan showed that iron and magnesium oxide content of the soils from basalt are more than the soils from basaltic alluvium while silicon ,aluminum, and potassium oxide content showed a reverse trend. The weathering indices like lower Al_2O_3/Fe_2O_3 , CEC, SiO_2/R_2O_3 and K_2O/N_2O molar ratios, reflected advanced stage of weathering in basaltic soil compared with their basaltic alluvial counterpart. (Singh *et al.,* 1995).

Rudra Murthy *et al.* (1996) found that passive pedogenic factors were important in the formation of associated red and black pedons occurring in close proximity (North Karnataka).

F. Classification :

Classification is the grouping of objects in some orderly and logical manner into compartments.

The word "Chernozem" or black earth was first coined by the Russian scientist Dokuchaiv (1879) for a vast area of black soils of U.S.S.R.

Leather (1898) first distinguished black cotton soil or regur soils in India as one among the major soil groups of India.

Indian blacksoils come under the chernozem soils due to the fact that:

(I) They are all black in colour.

(ii) Neutral to slightly alkaline in reaction.

(iii) Highly base saturated, mainly with calcium.

(iv) Well defined granular or crumb structure .

But fundamental difference are

(I) Low in humus content of the soil.

(ii) Calcareous nature of surface soils.

(iii) Absence of accumulation of $CaCO_3$ in certain soils due to shallower depth.

From all these pedogenic considerations, Rabinson (1932), Basu (1942) proposed that it would be safe to class these soils tentatively in a separate group altogether and termed them as "Immature Tropical Chernozems."

Bal(1943) suggested that soils derived from the weathering of trap in particulars, which are black in colour, heavy in character and are climatogenically suited for the growth of cotton are known as "Black cotton soils or regur soils". Similarly Hosking (1935) had described similar soils as dark clay soils in Australia. Vander Merwe(1940) has described similar soils as dark clay soils in South Africa. Tamhane (1950), Desai (1942), have also termed these soils as "Tropical chernozem".

Sharma and Bhargav (1973) classified some black soils of Tungabhadra catchment area in Mysore state. Profiles of eight black soils were described and classified according to the "7th Approximation " out of which seven were Vertisols and one was Inceptisols.

Two vertisol profiles developed under different physio-graphic units of Orissa were studied for their morphology, physico-chemical characteristics of soil and mineralogy of fine sand fractions. Some differences exist between the two profiles with regard to primary mineralogical composition, physiography and lithology. But the soil forming processes that are operative result in a similar type of soil formation. Both are classified as Ustalfic Pellusterts. (Sahu *et al.*, (1982).

Four black soils under Bargi irrigation project in Madhya Pradesh(Kausal *et al.* 1986) contain a uniform dark brown clay solum, with intersecting slickensides and parallelepiped aggregates. The soils are neutral to alkaline with the particle size class of fine to very fine, and thus, classified as vertisols .

Tiwari *et al.* (1989) attempted to characterise and classify red, black and yellow soils of Rajmal trap of Bihar in a toposequence. Various morphological, physico-chemical and chemical properties of these soils reveal that topographical situations associated with different moisture and drainage conditions were instrumental bringing the changes in soils. Black soils are Inceptisols, Vertisols and Entisols.

Morphology and other characteristics of Nimkheda soil in Jabalpur, Madhya Pradesh were studied in relation to topography (Prasad *et al.,* 1989). Taxonomically, these soils were classified into Alfisols, Entisols, Inceptisols, Mollisols, and Vertisols. Similarly Diwankar and Singh (1992) classified the soils of Tal land in old alluvial region as vertisols.

Sharma *et al.* (1993) studied six soil series in the hilly parts of soan rivers catchment in Himachal Pradesh. All the soil series excepting pandogha series were characterised by absence of `B' horizon and showed very profile development and were put under Entisols. The soils of Pandogha series showed the presence of an Ochric epipedon, underlain by the sub-surface horizon

showing absence of rock structure for at least half of the volume and qualified only for cambic horizon and order Inceptisols.

A detail soil survey was made by Das and Sahu (1994) in Nedisahi, mini water shed in Phulbani district of Orissa and found that, in Sidingi area clay content increased down the depth with presence of this patchy clay cutans forming argillic horizon because of high rainfall and well drained condition of the substratum and were classified as Aeric Kanhaplic Haplustalf and Aeric Kanhaplustalf. But the Nedisahi series located in medium valley position, was moderately well drained, removal of free F_2O_3 was restricted resulting in some structural development, Fe, Mn concretion formations and qualified for the presence of cambic horizon and was classified as Aridic Ustochrepts.

Panigrahi and Sahu (1995) studied four pedons from a lateritic zone and three pedons from a mixed red and black soils under subtropical monsoonic climate of Nayagarh district, Orissa in a toposequence indicated shallow sandy profiles in the upper ridges and deep clay loam at the bottom. There was an increase in clay organic matter down the profile. The upper ridge soils and mid upland soils were classified under Alfisols and the soils of mid lowland were classified under Incetisols.

Prasad *et al.* (1995) studied 3 pedons in Nasik districts and reported that soils developed from semiarid climate with very deep, moderately well drained and clayey were classified as *Chromic Haplusterts*. Singh *et al.* (1995) classified blacksoils developed from basalt and basaltic alluvium in Rajasthan as *Chromic Haplusterts* and *Tropic Haplusterts*.

Sahu *et al.* (1997) studied four pedons of an river flood plain under salandi irrigation command of eastern coastal region of Orissa and found that gradual increase of clay and development of structure down the depth indicated presence of cambic horizon. Fluctuation of water table, alternate wet and dry

condition in an irrigated regime have given rise to formation of Fe and Mn concretions and lime nodules in th sub-surface horizons. Soils were imperfectly drained, neutral to alkaline and the pH values increased down the depth. A significant positive correlation was obtained between clay and C.E.C. (r=0.92**). Soils were of medium fertility. Soils of the higher elevation were classified as Aeric Haplaquepts and those of lower elevation as Typic Haplaquepts.

Surekha *et al.* (1997) classified 10 deep black soil profiles from 8 districts of Andhra Pradesh and classified as *Haplusterts.*

Anita *et al.* (1998) classified the black soils of Gurazala Mandal of Guntur in Andhra Pradesh and reported presence of surface cracks, slickensides, fine texture, gilgai micro-relief and lime concretion. The soils are deep to very deep and are classified as Vertisols. Bharambe *et al.* (1999) studied the soil profile from Majalgaon canal command area and found the the soils are mostly vertisol with high clay content, Slow to moderately slow drainability. These soils are neutral to alkaline in reaction, calcareous in nature, with low to medium fertility status of available N,P and K, high CEC dominated by exchangeable Ca^{2+} followed by Mg^{2++}, sufficient in D.T.P.A. extractable Fe, Mn, Cu and marginal to sufficient in available Zn content.

Challa *et al.* (2000), characterised some problematic vertisols in semiarid ecosystem of Maharashtra plateau and found that their colour ranged from greyish brown to dark yellowish brown. Sodium absorption ratios have increased with depth and attained maximum in slickenside zone. In general Cl^-, SO_4^{2-} , HCO_3^- are dominant in the soil environment. Based on the properties soils were classified as *Halic Hapusterts* and *Sodic Haplusterts.*

CHAPTER - III

MATERIALS AND METHODS

CHAPTER -III

MATERIALS AND METHODS

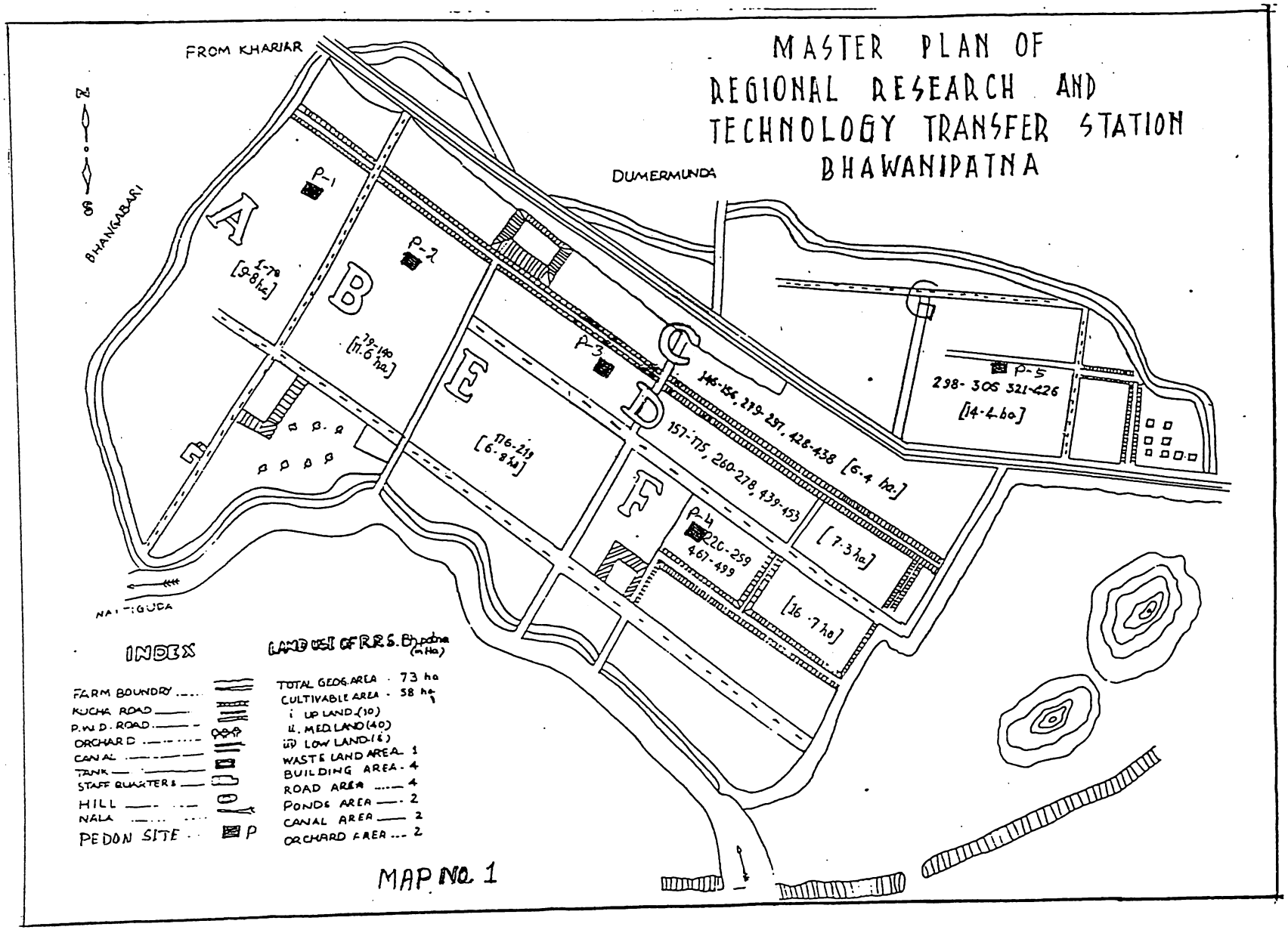
1. General features :

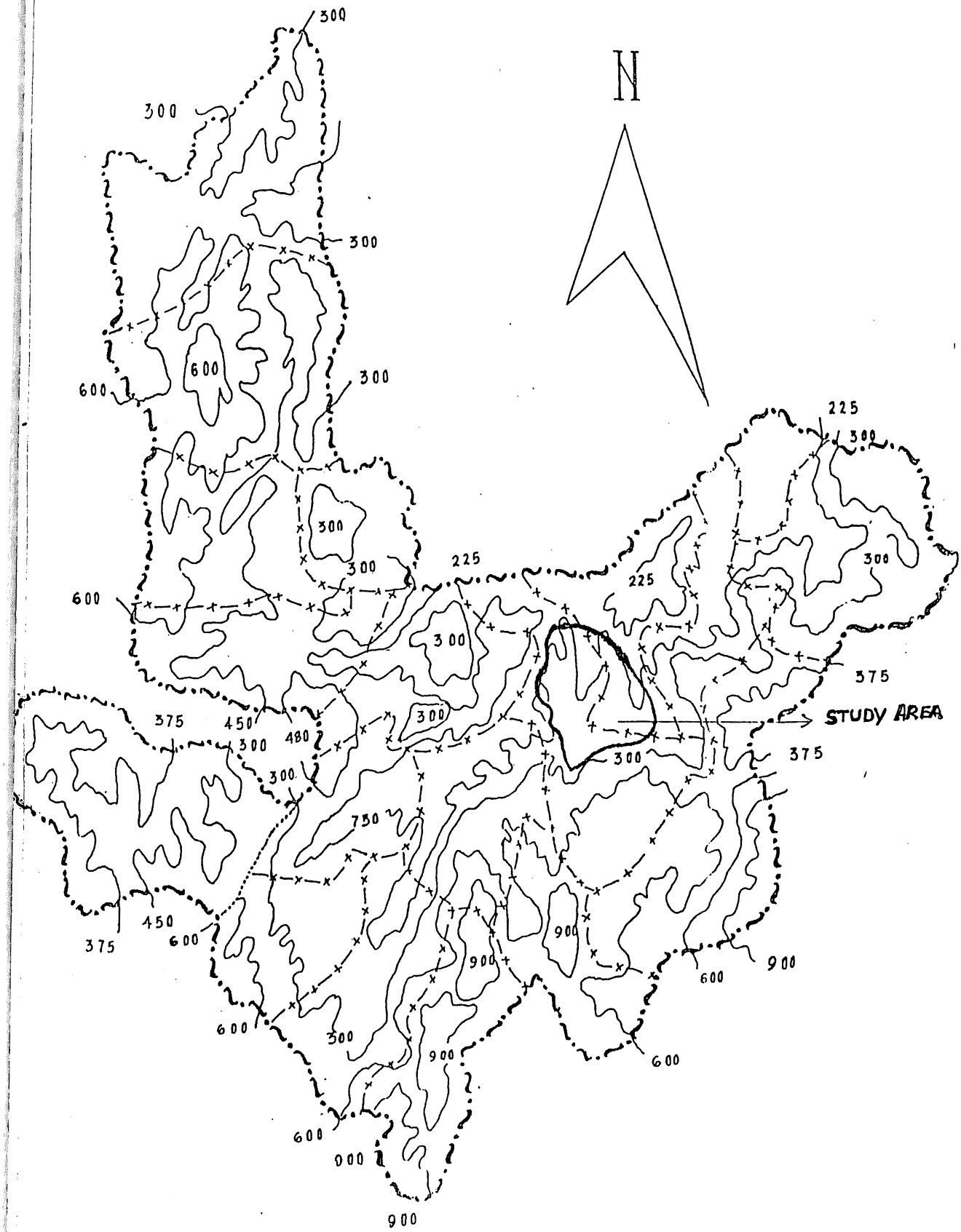
Regional Research and Technology Transfer Station(RRTTS), Bhawanipatna in the district of Kalahandi, Orissa which is in the western undulating agro-climatic zone was established in 1983. It is situated between 19.58 ^{0} N latitude and 83.12^0 E longitude covering an area of 73.0 ha, out of which 58.0 ha belong to cultivable area. It is divided into 7 representative blocks namely A, B, C, D, E, F, G and Bhawanipatna-Khariar road divides this Research station into two parts (Map 1). It is mostly a valley plain and different hills and hillocks surround this research station (Map 2).

Climate :

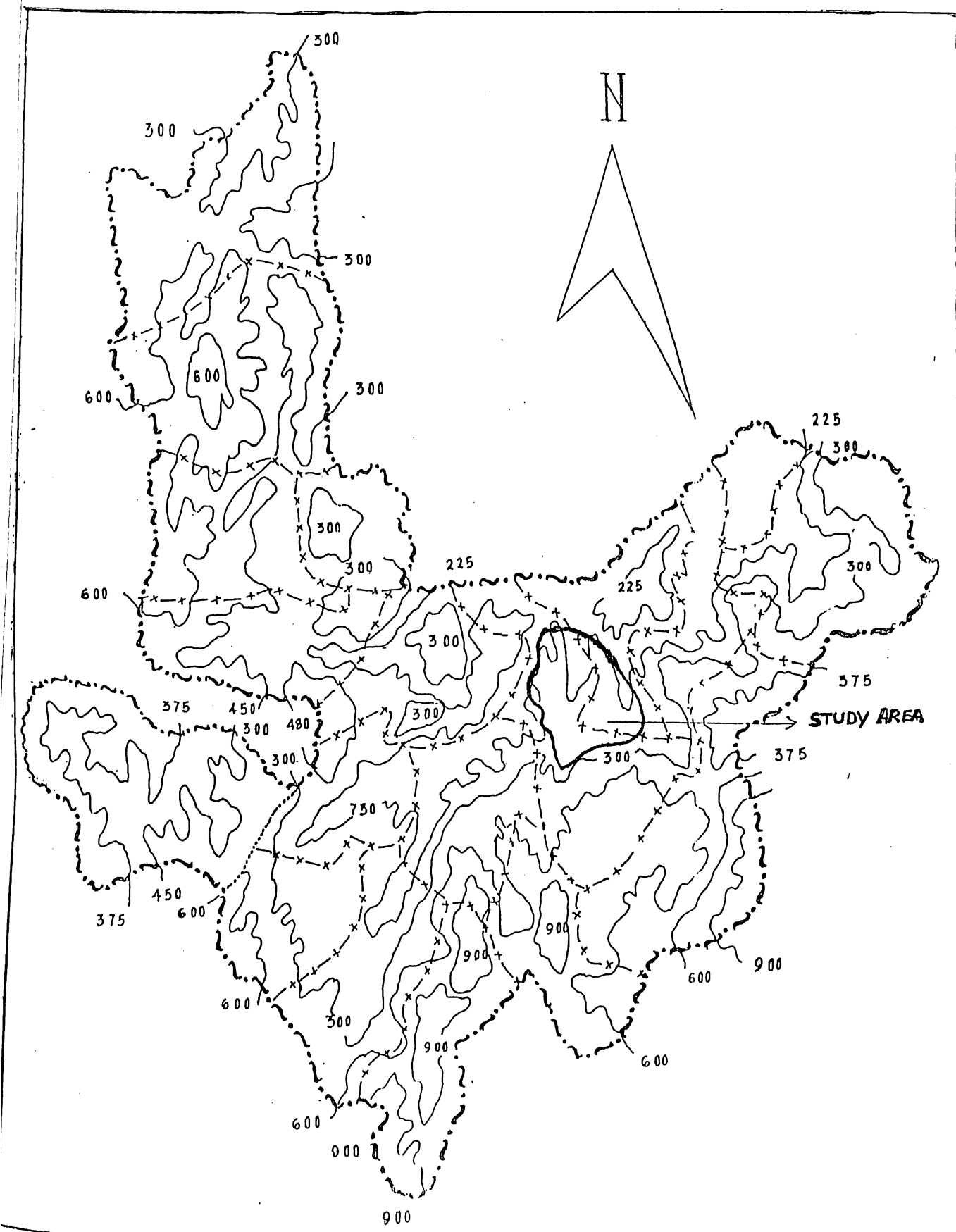
The climate of the zone is hot and moist subhumid characterised by a hot and dry summer , erratic rainfall in monsoon season and extreme cold in winter. Annual average rainfall varies from 960-1617 mm (S.D. 210 to 446 mm).About 90% of the rainfall is received from S-W monsoon during middle of June to October. Rainfall is mostly erratic and punctuated generally with long dry spells, which is drought prone.

The maximum temperature ranges from 28 to 45^0 C and minimum temperarture from 12 to 29^0 C. The relative humidity varies from 25 to 85%. The details with regard to climate, land and other features are given in Table 1


MASTER PLAN OF
REGIONAL RESEARCH AND
TECHNOLOGY TRANSFER STATION
BHAWANIPATNA
FROM KHARIAR
DUMERMUNDA
BHANGABARI
NAI GUDA
N
S
A
B
C
D
E
F
P-1
P-2
P-3
P-4
P-5
1-78
[9.8 ha]
79-140
[11.6 ha]
116-219
[6.8 ha]
146-156, 279-297, 428-438 [6.4 ha]
157-175, 260-278, 439-453
[7.3 ha]
220-259
467-499
[16.7 ha]
298-305 321-426
[14.4 ha]
INDEX
FARM BOUNDRY
KUCHA ROAD
P.W.D. ROAD
ORCHARD
CANAL
TANK
STAFF QUARTERS
HILL
NALA
PEDON SITE
P
LAND USE OF R.R.S. Bhawanipatna (in Ha)
TOTAL GEOG. AREA - 73 ha
CULTIVABLE AREA - 58 ha
i UP LAND (10)
ii. MED LAND (40)
iii LOW LAND (8)
WASTE LAND AREA - 1
BUILDING AREA - 4
ROAD AREA - 4
PONDS AREA - 2
CANAL AREA - 2
ORCHARD AREA - 2
MAP NO. 1



MAP NO.- 2 CONTOUR MAP OF WESTERN UNDULATING ZONE. SCALE:- 1 C.M = 13 K.M.



MAP NO.- 2 CONTOUR MAP OF WESTERN UNDULATING ZONE. SCALE:- 1 C.M = 13 K.M.

Table 1 : Climatic & Physiographic data of RRTTS, Bhawanipatna

1.	Mean annual rainfall (mm)	:	1354
2.	Average annual temperature(^{0}C)		
	(a) Maximum	:	28 to 45
	(b) Minimum	:	12 to 29
3.	Average annual relative humidity(%)	:	25 to 85
4.	Agro-climatic zone	:	Western undulating zone
5.	Climatic Classification	:	Hot and moist sub-humid
6.	Parent material	:	Granite gneiss
7.	Height from M.S.L (m)	:	300
8.	Latitude	:	19.58^0 N.
9.	Longitude	:	83.12^0 E
10.	Total geographical area	:	73.0 ha
11.	Total cultivable area	:	58.0 ha
	a) Upland	:	10.0 ha
	b) Medium land	:	40.0 ha
	c) Low land	:	8.0 ha

Pedon exposure and collection of soil samples :

Field traversing across the RRTTS, areas under study was done on 17th February, 2000. Sites for exposure of pedons were selected taking the ground cover, micro relief, subdivisional (blocks) units, surface drainage, proximity to drainage channel etc. into consideration to have best representative soil samples for that area. Profile pits of approximately 1m x 1m x 1.5m dimensions

were dug. The wall facing the sun at the time of study was carefully cleaned with a shovel. Thickness and morphological features of each horizon were recorded in the format and soil samples horizonwise were collected, kept in polythene packet with label indicating pedon and horizon number. Photograph of each pedon indicating horizons was taken. Besides profile samples, composite surface soil samples adjoining each pedon were also collected.

Materials :

The details of the 5 pedons which were exposed are given below and indicated in the map of the research station.

Pedon -1 (A)- Upland, backside of K.V.K. building in Block -A.

Pedon-2(B)-Medium land, 100m . south side of Khariar-Bhawanipatna road in block B.

Pedon-3(D)- Medium land, 100m south side of Khariar -Bhawanipatna road in block -D.

Pedon-4 (F) -Low land, 150m south side of Khariar-Bhawanipatna road, in block -F.

Pedon-5 (G)- Upland, 250m west of RRTTS, office building in block-G.

Processing of soil samples :

The soil samples were air dried, ground with a wooden mortar and pestle and passed through a 2 mm sieve. The samples remaining on the sieve were discarded after weighing and the samples passing through the sieve were preserved in plastic bottles with cover, labelled and stored in a dry place for further analysis.

Methods of Analysis

a) Methods for Physical analysis :

1. Soil colour :

The colour of the air dried soil samples were determined by matching the colour with Munsell's soil colour chart.

2. Mechanical composition :

The particle size analysis to determine the percentage of sand, silt and clay was carried out by modified Bouyoucos hydrometer method as described by Jackson (1976) and Sodium oxalate was used as dispersing agent and the percentage of sand, silt and clay fractions were determined. Textual classes were found out using International Triangular Diagram.

3. Bulk density, particle density :

Bulk density, particle density and percentage of porespace were determined by adopting the procedures as outlined by Chopra and Kanwar (1986)

b) Methods for chemical Analysis :

1. Soil reaction (pH) :

The pH soil samples were determined in 1:2 soil:water suspension by means of glass electrode using "SYSTRONIC" model 335 digital pH meter.

2. Electrical conductivity (E.C.)

The electrical conductivity of 1:2 soil:water suspension was determined by using "ELICO" model CM82-T conductivity bridge.

3. Organic carbon :

The organic carbon of soil was determined by modified Walkley and Black's rapid titration method. One gram of processed soil sample was treated with 10ml of 1N $K_2Cr_2O_7$, 20 ml of concentrated H_2SO_4 and were mixed thoroughly; kept for 30 minutes in dark for the digestion to be completed. Then 200 ml of distilled water was added and titrated against 0.5 N Ferrous Ammonium Sulphate solution using orth-ophenanthroline ferrous complex (Ferroin) indicator as described by Chopra and Kanwar(1986).

4. Calcium Carbonate or Free lime :

Free Carbonate as $CaCO_3$ equivalent was determined by the "Acid neutralization method" Five grams soil was treated with 10 ml of 0.5 N HCl, boiled for 5 minutes followed by cooling. Then 50 ml of distilled water was added and the unreacted acid was found out by titrating against 0.1 N NaOH using phenolphthalein indicator as per the procedure outlined by Page *et al.* (1982).

5. Cation Exchange Capacity (C.E.C.) :

The cation exchange capacity (C.E.C.) of soil was determined by centrifuge method by leaching with neutral normal ammonium acetate, as outlined by Page *et al.* (1982). In a centrifuge tube 2.5 gm soil was leached twice with 25 ml neutral normal NH_4OAc each time by shaking for 30 minutes followed by centrifugation for 15 minutes . Then the soil samples were washed with 60% ,80%, and absolute alcohol successively until the soil was free of chloride (No white precipitation with $AgNO_3$). The C.E.C. was then determined by distilling off

the adsorbed ammonium into 20 ml of 2% boric acid medium and titrating it against standard HCl using bromo-cresol-green and methyl red mixed indicator.

6. Exchangeable Cations :

Na^+ and K^+ :

Exchangeable Na^+ and K^+ of the soil present in the ammonium acetate leachate collected during C.E.C. determination were determined by "ELICO" model CL22D digital flame photometer.

Ca^{2+} and Mg^{2+} :

Exchangeable calcium and magnesium from the same leachate were determined after it was evaporated to dryness, digested with Aquaregia (HNO_3 : HCl=1:3) and concentrated HCl, then washed with dilute HCl, filtered and finally made to the original aliquot volume as described by Page *et al.* (1982).

Ca^{2+} + Mg^{2+} :

Ten ml of aliquot was diluted to 100 ml, 15 ml of buffer solution (NH_4Cl-NH_4OH), 10 drops each of hydroxyl amine hydrochloride and triethanol amine were added, warmed for 3 minutes, cooled, 10 drops of EBT (Eriochrome black T) indicator solution was added and titrated against standard EDTA solution.

Ca^{2+} :

Ten ml of aliquot was added with 10 drops each of hydroxyl amine hydrochloride and triethanol amine, 5 ml of 10% NaOH, 1ml of calcon indicator and titrated against standardized EDTA to a blue colour end point using calcon as the indicator.

Mg^{2+} :

Exchangeable Mg^{2+} of the soil was determined by subtracting the value of Ca^{2+} from that of (Ca^{2+} + Mg^{2+}) estimated earlier.

7. Available nutrients :

Nitrogen :

Available nitrogen was determined by alkaline permanganate method as outlined by Subbiah and Asija (1956). Nitrogen released in the form of ammonia during distillation of 20g of soil with 100 ml of 0.32% $KMnO_4$ and 100 ml of 2.5% NaOH, absorbed in 20ml of 2% boric acid with mixed indicator was titrated against standard HCl.

Phosphorus :

Available phosphorus in soil was determined by Olsen method (Olsen *et al.*, 1954) using 0.5 M $NaHCO_3$ as extracting solution in the ratio of 1:20 with soil and was estimated colorimetrically.

Potassium :

Available potassium was determined by shaking 5g of soil in 25 ml neutral normal ammonium acetate for 5 minutes and the reading of extract was taken in "ELICO" model CL 22 digital flame photometer. (Page *et al.* 1982).

Sulphur :

Available sulphur was determined by turbidometric procedure as outlined by Page *et al.*, (1982). Five grams soil in 25 ml of 0.15% $CaCl_2$ solution was shaken for 30 minutes. Ten ml of extract so obtained after filteration was added with 10ml of 10 ppm seed solution and 5 ml of gum acacia. Finally turbidity was

developed by the addition of 0.3g $BaCl_2$ and measured spectrophotometrically at 440 nm.

Boron :

Available boron was determined by Azomethine -H colorimetric method with hot water extract as described by Dible *et al.* (1954). Thirty grams air dried soil were refluxed with 60 ml of distilled water and filtered. Four ml of the extract was added with 6 ml of buffer reagent, 2 ml of Azomethine - H reagent and measured colorimetrically after 1 hour.

Iron, Copper, Zinc and Manganese :

Available Fe, Cu, Zn, Mn, were determined by atomic absorption spectrometer (Lindsay & Norvell, 1978). Twenty gram of soil with 40 ml of 1 M NH_4HCO_3-0.005M DTPA as extracting solution was shaken for 6 hours and filtered. Concentration of the nutrient element in the extract was determined with Chemito model AA-203 atomic absorption spectrophotometer.

CHAPTER - IV

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, the results of the investigation along with appropriate discussions are presented in the following heads for convenience.

1. Morphological characteristics of the soil pedons.
2. Physical characteristics including mechanical composition, bulk density, particle density,percentage pore spaces.
3. Chemical characteristics with regard to pH, organic carbon, $CaCO_3$ equivalent, cation exchange capacity (C.E.C.) and exchange compositions etc.
4. Available macro-nutrient status of the soils.
5. Available micronutrient status of soil.
6. Soil genesis.
7. Soil classification as per soil Taxonomy

A soil survey describes the characteristics of soils in a given area, classifies the soils according to a standard system of classification, plots the boundaries of the soils on a map and makes predictions for the behaviour of soils. The information collected in a soil survey helps in the development of land use plans and evaluates and predicts the effect of land use on the environment Soil Survey Manual, 1995). During soil survey, the study of morphology of soil profiles is one of the most important aspect. Marbut (1921) emphasized strongly

that the classification of soil should be based on morphology instead of theories of soil genesis. Soil morphology provides a firm basis to group the results of observations, experiments and practical experience and to develop integrated principles that predict the behaviour of soil.

The system of classification discussed in Soil Taxonomy(1975) is dynamic and will change as new knowledge is obtained. Before adopting the comprehensive system of soil classification in 1960 in India, the soils were being classified as per Genetic system of soil classification (Baldwin *et al.*, 1938 as modified by Throp and Smith, 1949). As per this classification, the soils of Orissa were being classified into 8 groups i.e. Red soil, Laterite and lateritic soil, Black soil, Alluvial soil, Mixed red and black soil, Red and yellow soil, Coastal saline soil and Brown forest soil. The soils of Bhawanipatna are mostly black soils. Difference and morphology, physiography, microrelief and time have given rise to different categoriesed of soils. As has been described later under "Soil classification", the soils of RRTTS, Bhawanipatna can be categorized under two series i.e. Bhawanipatna-1 (P-1,2,3,4) and Bhawanipatna-2(P-5). For better understanding and comprehension of the soils of the RRTTS, their characteristic properties and land use pattern, the different pedons are described under the above two series.

Pedon description

1. Morphological characteristics of the soil profile.

Five pedons under RRTTS, Bhawanipatna were studied. The morphological descriptions are presented below. (Morphological description in

reviated from are also presented in Table 2. Colours for moist state are cated by "m".

lon 1 (Block - A)

: characteristics

ation	:	(A block), south side (100m) of Khariar Bhawanipatna road, backside of K.V.K. building and 50 m west of farm road leading to threshing floor.
d form	:	Upland, cultivated
ief/ Elevation	:	Slightly sloping
pe class	:	B (1-3 %)
pe direction	:	N-S
face condition	:	Cultivated
face drainage	:	Model
sion	:	e1
t and alkali	:	Nil
ural vegetation	:	*Acacia nilotica, Azadirachta indica, Dalbergia latifolia, Tectona grandis.*
ıd use	:	Kharif paddy-Fallow
›und water table	:	More than 1.5 m
ent material	:	Granite - gneiss

netic Horizon	**Depth(m)**	**Description**
	0-0.14	Light brownish gray (10YR 6/2), gray brown (10 YR 5/2 m); clay loam; weak, medium,

View of pedon 1

subangular blocky; slightly hard, friable, sticky; cracks of 2-3 cm wide; gilgai micro-relief, fine, fibrous, many, imped roots, moderate permeability; neutral (pH-6.5) clear, smooth boundary;

B ~~A12~~ 0-14-0.35 Dark gray brown (10YR 4/2), dark gray (10YR 4/1m); clay; strong, medium, angular blocky; hard, friable, sticky and plastic; few Fe, Mn concretion; cracks of 1-2 cm wide, ~~slickensides and shiny pressure faces~~; fine, fibrous, medium, imped roots; moderate permeability; neutral (pH-7); clear, smooth boundary;

Bss1 ~~A13~~ 0.35-0.57 Brown (10YR 4/3), dark gray brown (10 YR 4/2 m); clay; strong, coarse, angular blocky; very hard, very firm, very sticky and plastic; many Fe, Mn concretion; cracks of 1-2 cm wide, slickensides; fine fibrous, few roots; slow permeability; mildy alkaline (pH-7.4); gradual, smooth boundary;

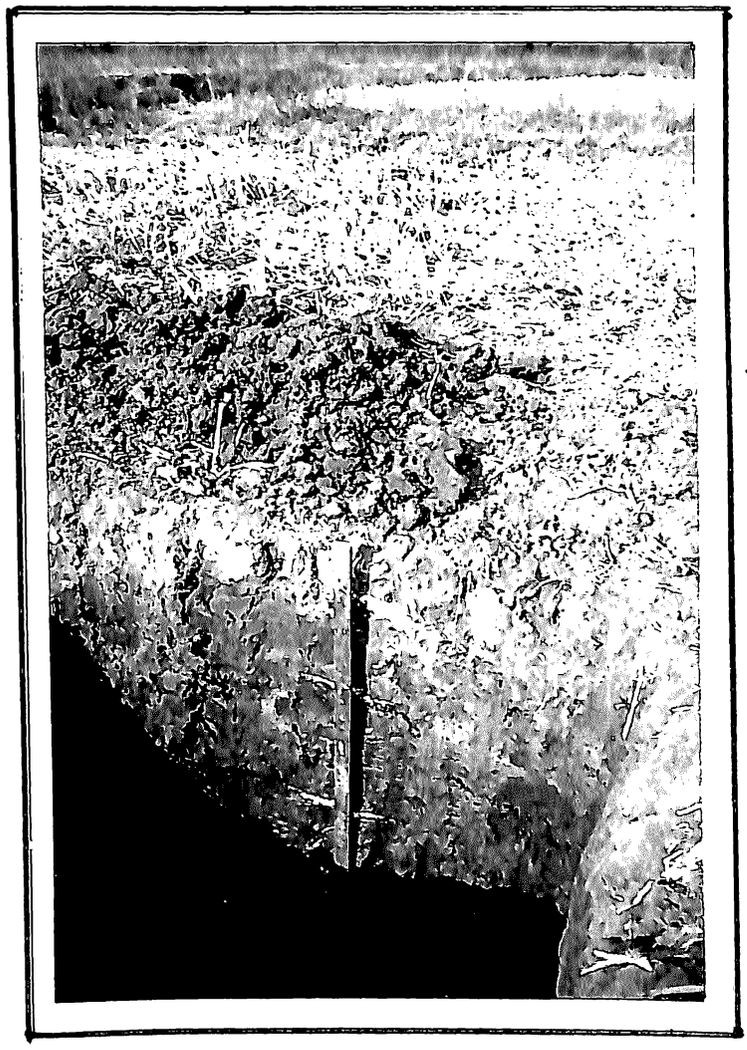
Bss2 ~~A14~~ 0.57-1.25 Brown (10YR 4/3),very dark gray brown (10YR 3/2m); clay; strong, coarse, angular blocky; very hard, very firm, very sticky and very plastic; many Fe, Mn concretion; cracks of 1-2 cm wide, slicknsides; slow permeability; mildly alkaline (pH-7.42).

Pedon 2 (Block - B)

Site characteristics

Location	:	(B block), South side (100m) of Khariar-Bhawanipatna road, 60m east of farm road leading to threshing floor
Land form	:	Medium land, cultivated
Relief/ Elevation	:	Terraced levelled land
Slope class	:	A(0-1%)
Slope direction	:	E - N
Surface condition	:	Cultivated
Surface drainage		Moderate
Erosion	:	e1
Salt and alkali	:	Nil
Natural vegetation :	:	*Acacia nilotica, Azadirachta indica, Dalbergia latifolia, Tectona grandis.*
Land use	:	Kharif paddy-Fallow
Ground water table	:	More than 1.35 m
Parent material	:	Granite - gneiss

Genetic Horizon	Depth(m)	Description
Ap	0-0.12	Dark gray brown (10 YR 4/2), dark gray (10 YR 4/1m); clay; moderate, medium, subangular blocky; hard, friable, very sticky and plastic; few Fe, Mn concretion; cracks



View of pedon 2

of 2-3 cm wide, gilgai micro-relief many fine, fibrous imped roots; moderate permeability; neutral; (pH-6.75); clear, smooth boundary;

B ~~A12~~ 0.12-0.30 Very dark gray brown (10YR 3/2), dark gray (10YR 4/1m); clay; strong, coarse, angular blocky; hard, firm, very sticky and plastic; many Fe, Mn concretion; cracks of 1-2 cm wide, ~~slickensides and shiny pressure faces;~~ wedge shaped aggregate; few, fine, fibrous imped roots; slow permeability; neutral (pH-7.03); gradual, smooth boundary;

B881 ~~A13~~ 0.30-0.42 Brown (10YR 4/3), dark gray brown (10YR 4/2 m); clay; strong, coarse, angular blocky; hard, firm, very sticky and very plastic; few Fe, Mn concretion; irregular 1-2 cm lime nodules, strong effervescence; cracks of 1-2 cm wide, slickensides; wedge shaped aggregates; slow permeability; neutral (pH 7.19); gradual smooth boundary;

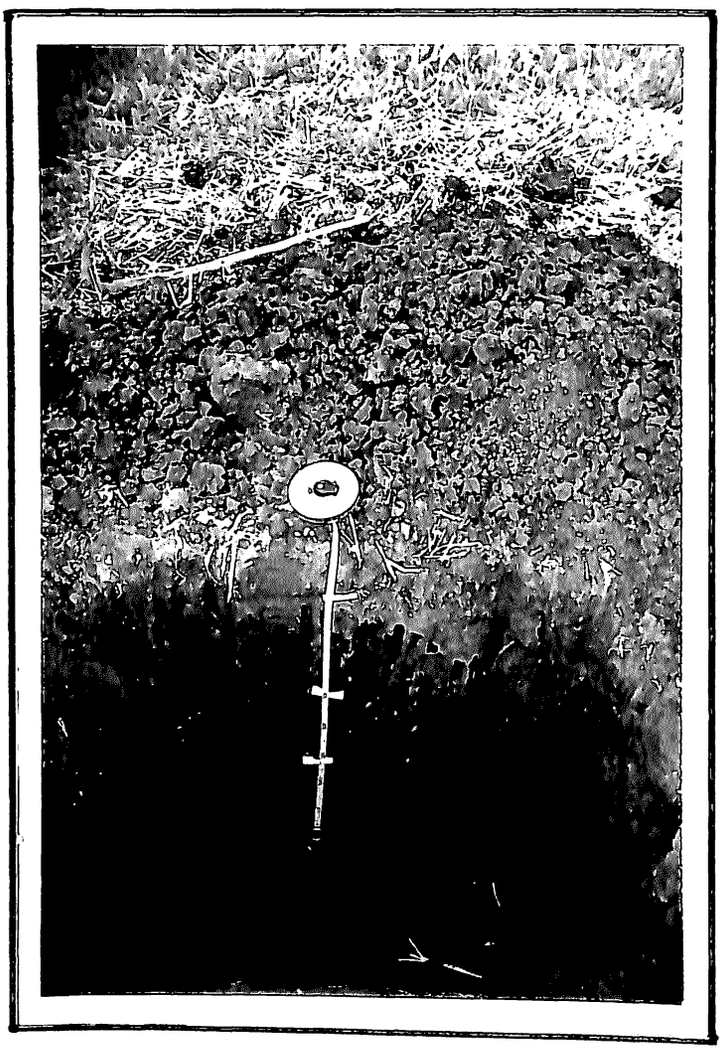
B882 ~~A14~~ 0.42-1.35 Dark gray brown (10YR 4/2), dark gray (10 YR 4/1m); clay; strong, coarse, angular blocky; hard, very firm, very sticky and very plastic; few Fe, Mn, Ca concretion, lime nodules of 1-2cm; strong effervescence; cracks of 1-2 cm wide, slickensides and shiny pressure faces; wedge shaped aggregates; very slow permeability; mildly alkaline (pH-7.67).

Pedon 3 (Block - D)

Site characteristics

Location	:	(D block)South side (100m) of Khariar-Bhawanipatna road and 150m west of Telecommunication tower.
Land form	:	Medium land
Relief/ Elevation	:	Gentle sloping
Slope class	:	B (1-3 %)
Slope direction	:	E - W
Surface condition	:	Cultivated
Surface drainage	:	moderate
Erosion	:	e1
Salt and alkali	:	Nil
Natural vegetation :	:	Babul (*Acacia nilotica), Azadirachta indica, Dalbergia latifolia, Tectona grandis.*
Land use	:	Kharif paddy-Fallow
Ground water table	:	More than 1.35 m
Parent material	:	Granite - gneiss

Genetic Horizon	Depth(m)	Description
Ap	0-0.14	Gray brown (10YR 5/2), dark gray brown (10 YR 4/2m); clay loam; moderate, medium, subangular, blocky; very hard, friable, very sticky and very plastic; cracks of 2-3 cm wide; gilgai micro-relief; many, fine, fibrous,



View of pedon 3

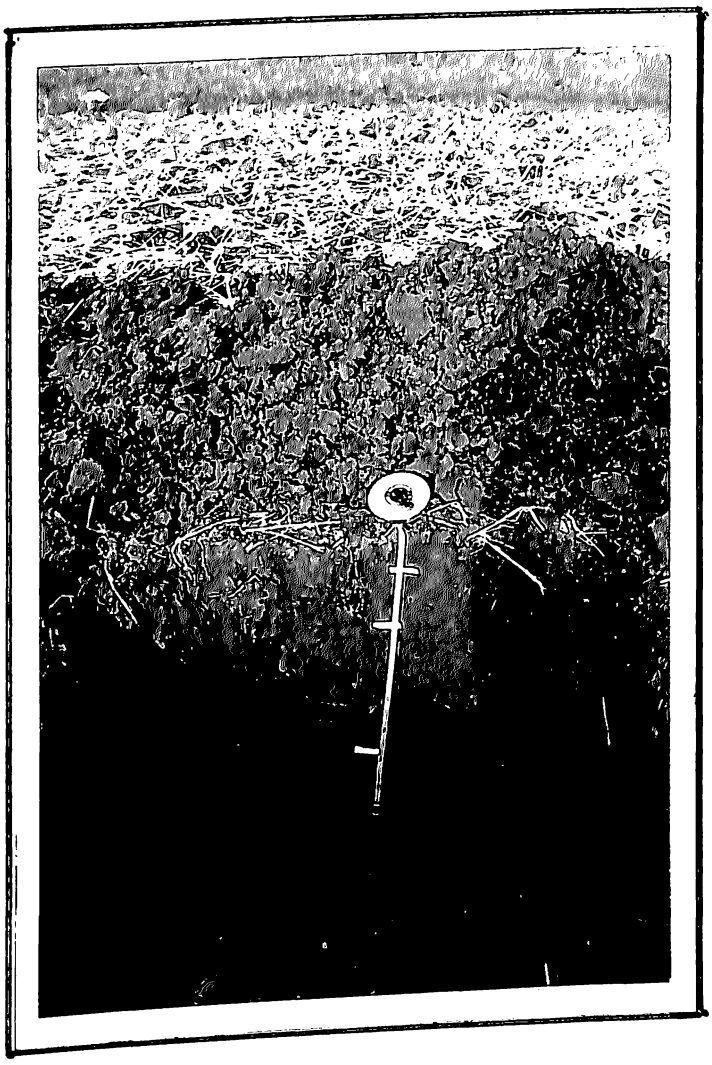
		imped roots; slow permeability; neutral (pH-6.53); clear, smooth boundary;
B ~~A12~~	0.12-0.40	Very dark gray (10YR 3/1), black (10YR 2/1 m); clay; strong, coarse, angular blocky; very hard, firm, sticky and plastic; few Fe, Mn concretion; cracks of 1-2cm wide, ~~slickensides~~; wedge shaped aggregates; few, fine, fibrous, imped roots; slow permeability; neutral (pH 6.69); gradual, smooth boundary;
Bss1 ~~A13~~	0.40-0.65	Very dark gray brown (10YR 3/2), very dark gray (10YR 3/1m); clay; strong, coarse, angular blocky; very hard, very firm, very sticky and plastic; few Fe, Mn concretion, irregular 1-2 cm lime nodule; cracks of 1-2 cm wide, slickensides, wedge shaped aggregates; very few fine, fibrous, imped roots; very slow permeability; neutral (pH - 6.93); gradual, smooth boundary;
Bss2 ~~A14~~	0.65-1.30	Dark gray brown (10YR 4/2), dark gray (10YR 4/1m); clay; strong, coarse, angular blocky; very hard, very firm, very sticky and very plastic; few Fe, Mn concretion and lime nodules; cracks of 1-2 cm wide, slickensides; very slow permeability; neutral (pH 7.16).

Pedon 4 (Block - F)

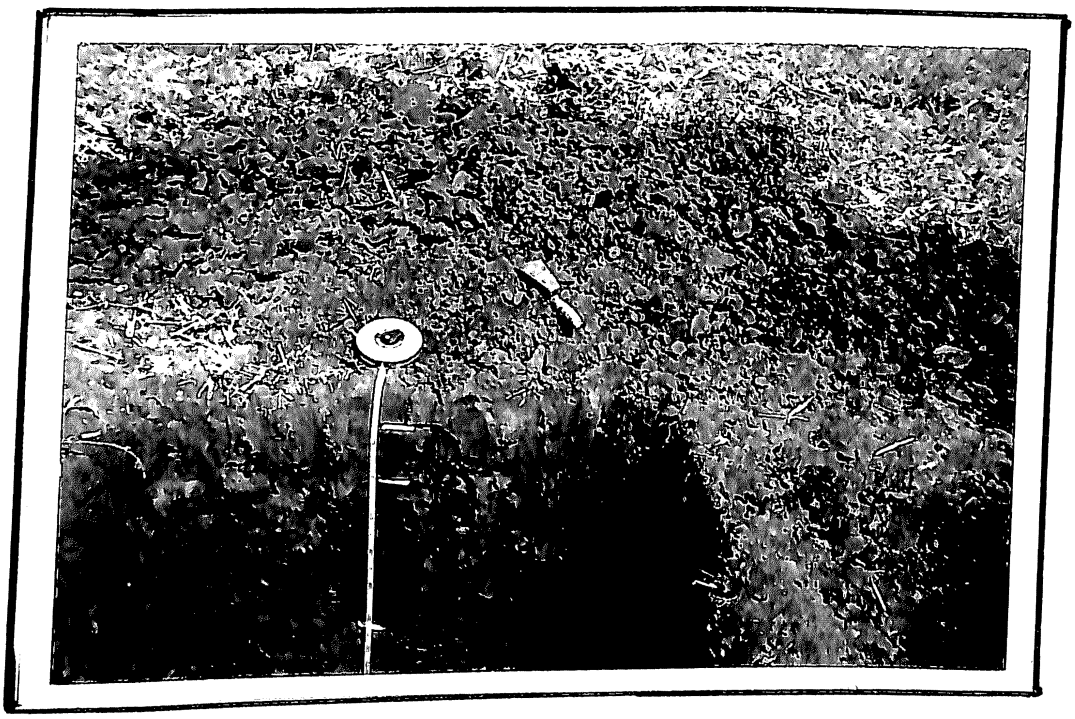
Site characteristics

Location	:	(F block), south side (150m) of Khariar-Bhawanipatna road and 50 m west of Telecommunication tower.
Land form	:	Lowland, cultivated
Relief/ Elevation	:	Slightly sloping
Slope class	:	B(1-3 %)
Slope direction	:	N - S
Surface condition	:	Cultivated
Surface drainage	:	Moderately slow
Erosion	:	e1
Salt and alkali	:	Nil
Natural vegetation :	:	*Acacia nilotica, Azadirachta indica, Dalbergia latifolia, Tectona grandis.*
Land use	:	Kharif paddy-Fallow
Ground water table	:	More than 1.25 m
Parent material	:	Granite - gneiss

Genetic Horizon	Depth(m)	Description
Ap	0-0.12	Very dark gray brown (10YR 3/2), very dark gray (10YR 3/1 m); clay; strong, coarse, angular blocky; very hard, friable, sticky and very plastic; cracks of 2-3 cm wide, gilgai micro-relief; many, fibrous, imped roots; clear, smooth boundary;



View of pedon 4



View of pedon 5

		plastic; cracks of 1-2 cm wide; many, fine, fibrous, imped roots, moderate permeability, neutral (pH - 6.5); abrupt, smooth boundary;
Bw1	0.12-0.25	Brown (10YR 5/3), dark gray brown (10 YR 4/2 m); clay loam; moderate, fine, subangular blocky; hard, firm,, slightly sticky and slightly plastic; many Fe, Mn concretion. cracks of 1-2 cm wide; fine, fibrous, medium, imped roots; moderately slow permeability; neutral (pH 7.3); clear, smooth boundary;
Bw2	0.25-0.67	Dark gray brown (10YR 4/2), very dark gray (10YR 3/1); clay loam; medium, coarse, angular blocky; hard, firm, sticky and plastic; many Fe, Mn and lime concretion, strong effervescence; cracks of 1-2 cm wide, ~~slickensides~~; few, fine, fibrous, imped roots, slow permeability, neutral (pH-7.3); gradual, smooth boundary;
Bss1 ~~Bw3~~	0.67-1.30	Dark brown (10YR 4/3), dark gray brown (10YR 4/2 m); clay loam; strong, coarse, angular blocky; very hard, firm, sticky and plastic; cracks of 1-2 cm wide, slickensides; very slow permeability; mildly alkaline (pH 7.45).

Table 2 Morphological characteristics of pedons

Pedons	Horizon	Depth(m)	Soil colour		Boundary	Textures	Structure	Consistence	Special features
			Dry	Moist					
1 (A)	Ap	0-0.14	10YR 6/2	10YR 5/2	cs	cl	2m sbk	dsh mfr ws wsp	cracks of 2-3 cm wide, gilgai micro-relief.
	B ~~A12~~	0.14-0.35	10YR 4/2	10YR 4/1	cs	c	3m abk	dh mfr ws wp	Few Fe, Mn concretion, 1-2cm wide cracks, ~~slickensides~~
	Bss1 ~~A13~~	0.35-0.57	10YR 4/3	10YR 4/2	gs	c	3c abk	dvh mvfi wvs wp	Many Fe, Mn concretion, cracks of 1-2 cm wide, slickensides
	Bss2 ~~A14~~	0.57-1.25	10YR 4/3	10YR 3/2	-	c	3c abk	dvh mvfi wvs wvp	Cracks of 1-2 cm wide, many Fe, Mn concretion, slickensides.
2 (B)	Ap	0-0.12	10YR 4/2	10YR 4/1	cs	c	2m sbk	dh mfr wvs wp	Few Fe, Mn concretion, crakcs of 2-3 cm wide, gilgai micro-relief.
	B ~~A12~~	0.12-0.30	10YR 3/2	10YR 4/1	gs	c	3c abk	dh mfi wvs wp	Many Fe, Mn concretion, 1-2cm wide cracks, ~~slickensides~~.
	Bss1 ~~A13~~	0.30-0.42	10YR 4/3	10YR 4/2	gs	c	3c abk	dh mfi wvs wvp	Few Fe, Mn concretion, irregular 1-2 cm lime nodules, cracks of 1-2 cm wide.
	Bss2 ~~ACca~~	0.42-1.35	10YR 4/2	10YR 4/1	-	c	3c abk	dh mvfi wvs wvp	Lime nodules of 1-2.5 cm, few Fe, Mn concretion, cracks of 1-2 cm wide slickensides and shiny pressure faces.
3(D)	Ap	0-0.12	10 YR 5/2	10 YR 4/2	cs	cl	2m sbk	dvh mfr wvs wvp	Cracks of 2-3 cm wide, gilgai micro-relief.
	B ~~A12~~	0.12-0.40	10 YR 3/1	10 YR 2/1	gs	c	3c abk	dvh mfi ws up	Few Fe, Mn concretion, cracks of 1-2 cm wide, ~~slickensides~~

Pedons	Horizon	Depth(m)	Soil colour		Boundary	Textures	Structure	Consistence	Special features
			Dry	Moist					
	Bss1 ~~AGca~~ Bss2	0.40-0.65	10 YR 3/2	10 YR 3/1	gs	c	3c abk	dvh mvfi wvs wp	Few Fe, Mn Conc. many lime nodules cracks of 1-2 cm wide, slickensides
		0.65-1.30	10 YR 4/2	10 YR 4/1	-	c	3c abk	dvh mvfi wvs wp	Few Fe, Mn concretion, many lime nodules, cracks of 1-2cm wide, slickensides
4(F)	Ap	0-0.12	10 YR 3/2	10 YR 3/1	cs	c	3c abk	dvh mfr ws wvp	Cracks of 2-3 cm wide, gilgai micro-relief.
	Bss1 ~~A12~~	0.12-0.30	10 YR 2/2	10 YR 2/1	gs	c	3c abk	deh mefi wvs wvp	Few Fe, Mn concretion, Irregular 1-2cm lime nodules, cracks of 1-2cm wide,. Slickensides with shiny pressure faces.
	Bss2 ~~A13~~	0.30-0.68	10 YR 3/2	10 YR 2/1	gs	c	3c abk	dvh mefi wvs wvp	Many Fe, Mn concretion, common lime nodules, cracks of 1-2 cm wide, slickensides
	Bss3 ~~AGca~~	0.68-1.25	10 YR 4/1	10 YR 3/1	-	c	3c abk	dh mefi wvs wvp	Many Fe, Mn concretion, and lime nodules, cracks of 1-2cm wide slickensides.
5(G)	Ap	0-0.12	10 YR 6/3	10 YR 4/2	as	sl	2f sbk	dsh mfr wss wsp	Cracks of 1-2 cm wide
	Bw_1	0.12-0.25	10 YR 5/3	10 YR 4/2	cs	cl	2f sbk	dh mfi wss wsp	Many Fe, Mn concretion, cracks of 1-2 cm wide, ~~slickensides~~
	Bw_2	0.25-0.67	10 YR 4/2	10 YR 3/1	gs	cl	2c abk	dh mfi ws wp	Many Fe, Mn lime concretion. 1-2 cm wide cracks, ~~slickensides~~
	Bss1 ~~Bw3~~	0.67-1.30	10 YR 4/3	10 YR 4/2	-	cl	3c abk	dvh mfi ws wp	Cracks of 1-2cm wide, slickensides

The abbreviations are as per Soil Survey Manual, (Soil Survey Staff, 1993)

Soilscapes of vertisols (black soils)and associated soils occurring extensively in different climatic zones including moist sub-humid regions of India are confined to an elevation of 300-900 m above mean sea level with high summer and mild winter temperatures. (Murthy *et al.,* 1982) The factors contributing to vertisols development are

i) Land forms in lower topographical situations.

ii) Medium to low precipitation during a specific period.

iii) High temperature.

iv) Alternate wet and dry period.

v) Basic character of rocks and parent material rich in alkaline earths and

vi) Restricted drainage

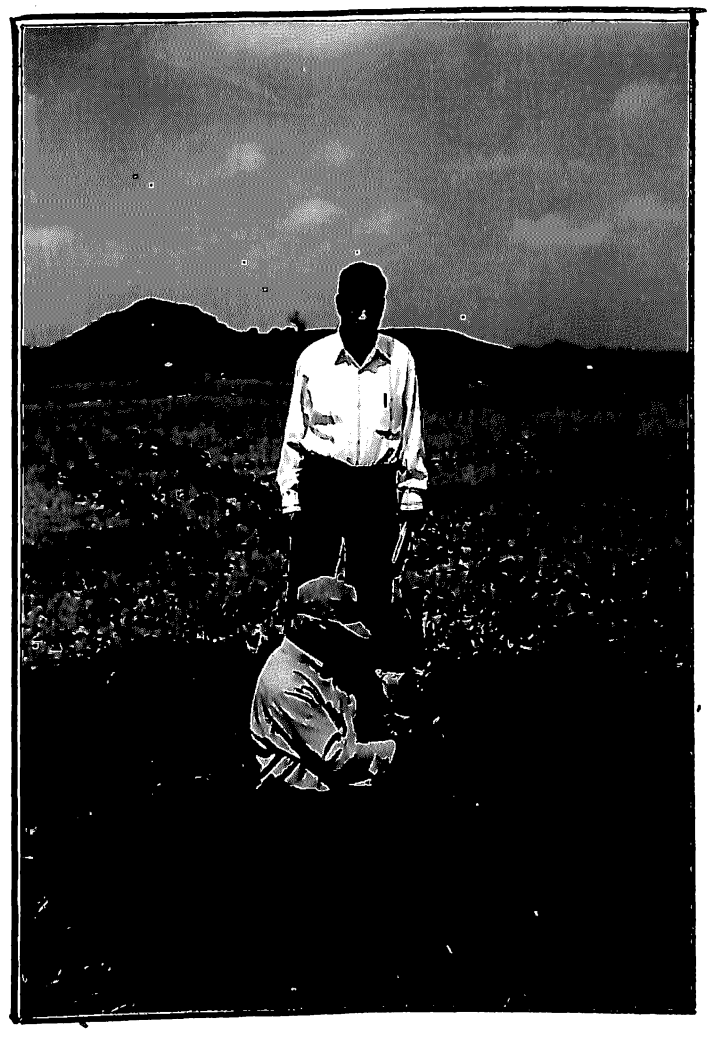
Morphology, is the index for identifying the genetic process in soil development attributing to unique properties of soil. While studying regurs in India, Simonson (1954) observed a slow and steady churning process within the pedon inhibiting the process of horizon differentiation and developing A-C profiles. Vertisols and soils of vertic subgroups have certain uncommon morphological features as compared with other soils. Vertisols morphology exhibit a high degree of uniformity throughout the profile, while the associated soil exhibit an isotropic properties through the profiles as such the diagnostic morphometric features in vertisol profiles should express the dominant role of the process of haploidisation by argillipedoturbation, inhibiting the process of horizonation.

Considering the morphological features and physiographic situations (Valley plains) as displayed in photoplate-6, it is seen that all the pedons excepting pedon-5 have AC profiles and exhibit a high degree of uniformity throughout the profile . But very little differentiation is observed in pedon-5, in which vertic properties like slickensides and shiny pressure faces could be observed in the lower horizons. The result are in conformity with the work of (Murthy et al 1982) with regard to vertisols/vertic subgroups.

Normally open shrinkage cracks of 2 to 5 cm wide tapering through depth and gilgai micro-relief constitute a normal surface features (Murthy *et al.,* 1982) which is observed in the present study. These cracks normally remain open for more than 150 cumulative days.

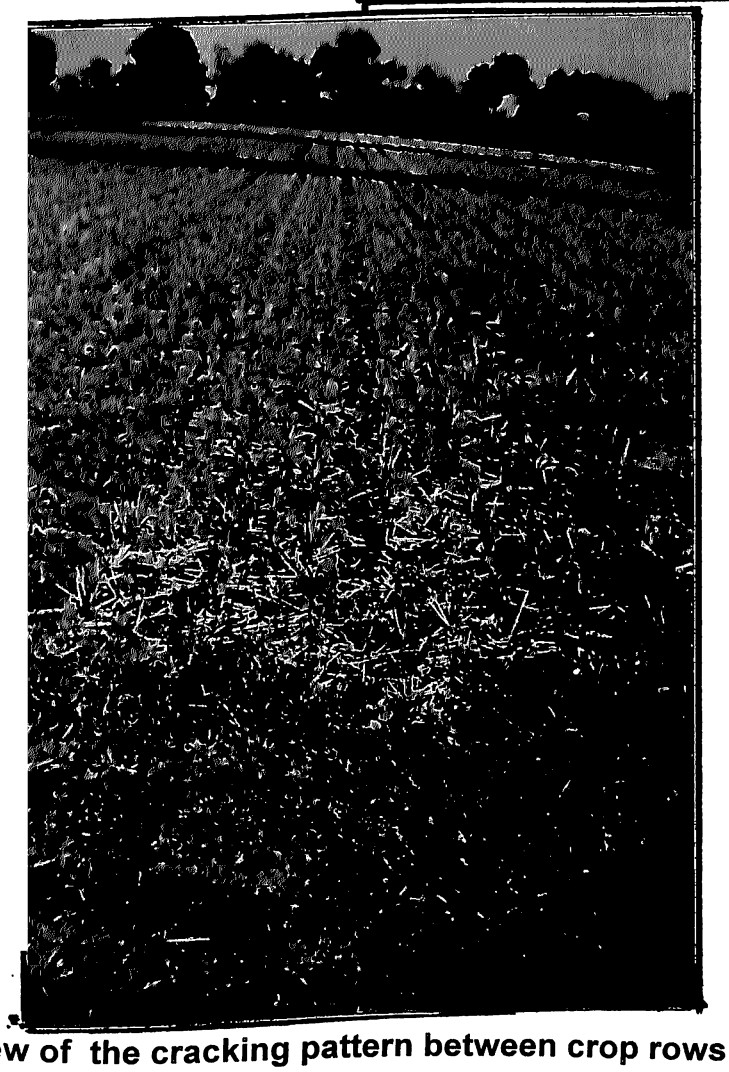
More over the cracking patterns as observed at the soil surface are approximately hexagonal in shape in the absence of any directional influence (Photo plate 7). But where crops are in rows, major cracks commonly predominate parallel to crop rows and midway between them (alley) and much smaller cracks within the crop rows (Photo plate 8). This pattern has been attributed to the proliferation of roots holding the soil together.

Because of deep and wide cracks in vertisols, the largest structural aggregates down to the depth of cracking are normally observed. The structure is mostly sub-angular to angular blocky. When the aggregates are broken, the fissures between peds show a tendency towards an oblique direction and consequently. the structural units acquires a flattened appearance. (Blokhuis,



6. View of the physiographic situations

7.View of surface cracks



iew of the cracking pattern between crop rows

1982). These flattened blocky elements are specific for the subsoil structure of vertisols which is observed in the present study.

Many authors have opined that the dark colour of vertisol might be due to clay/organic matter complex, Ca-humate complex with titaniferous magnetite etc. In the present investigation, the colour of the soil is mostly dark brown to very dark gray brown and it is almost uniform throughout the depth. As the organic matter content is low, the dark colouration in these soils might be partly due to ilmenite (14-87%) which is quite high along with other dark coloured ferromagnesian minerals. (Sahu *et al.,* 1982) Usually in vertisols, the colour value of dry soil ≤ moist soil and chroma of dry soil ≥ moist soil (Surekha *et al.,* 1977), which is also observed in the present study.

Fine to coarse irregular $CaCO_3$ nodules act as the diagnostic characters of vertisols (Raychoudhury *et al.,* 1963). The lime concretions usually increases with depth as is observed in the present investigation.

2. Physical characteristics:-

Optimum physical properties are essential requisites for productivity of black soils. A study of physical properties aims at providing tools for the proper management of the soil viz. irrigation, drainage, soil and water conservation, soil tillage, soil structure, improvement, soil aeration, and its consistency etc.

Data on mechanical composition and other physical characteristics are categorically presented in Table-3.

Table 3 Mechanical composition and physical properties of pedons

Pedon	Depth (m)	% coarse sand	% fine sand	% silt	% clay	texture	B.D. (Mg m^{-3})	P.D. (Mg m^{-3})	% pore spaces
1(A)	0-0.14	25	32.6	11.8	30.6	cl	1.43	2.70	47.0
	0.14-0.35	16.2	29.4	13.8	40.6	c	1.33	2.65	49.8
	0.35-0.57	20.6	24.0	13.8	41.6	c	1.32	2.65	50.2
	0.57-1.25	26.6	19.0	12.8	41.6	c	1.31	2.78	52.9
2(B)	0-0.12	20.6	25.0	14.8	39.6	c	1.38	2.74	49.6
	0.12-0.30	16.8	20.8	15.8	46.6	c	1.33	2.74	51.5
	0.30-0.42	18.0	19.6	13.8	48.6	c	1.31	2.65	50.7
	0.42-1.35	16.4	21.2	13.8	48.6	c	1.32	2.70	51.1
3(D)	0-0.12	21.2	39.4	11.8	31.6	cl	1.41	2.65	46.8
	0.12-0.40	16.6	29.0	16.8	37.6	c	1.38	2.75	49.8
	0.40-0.65	20.8	23.8	13.8	41.6	c	1.31	2.75	52.4
	0.65-1.30	21.6	21.0	12.8	44.8	c	1.31	2.70	51.5
4(F)	0.0-12	19.6	19.0	12.8	48.6	c	1.25	2.77	54.9
	0.12-0.30	19.6	19.0	11.8	49.6	c	1.26	2.75	54.2
	0.30-0.68	20.2	16.4	11.8	51.6	c	1.28	2.77	53.8
	0.68-1.25	19.0	16.6	11.8	52.6	c	1.30	2.70	51.9
5(G)	0-0.12	39.2	32.4	9.8	18.6	cl	1.38	2.70	48.9
	0.12-0.25	36.2	27.4	11.8	24.6	cl	1.33	2.65	49.8
	0.25-0.67	21.8	28.8	18.8	30.6	cl	1.28	2.74	53.3
	0.67-1.30	26.8	18.8	21.8	32.6	cl	1.25	2.74	54.4

Pedon 1 is a very deep profile (Photo plate 1) having clay content of 30.6% on the surface and maximum of 40.6 % in the subsurface. The value slightly increases down the depth. The texture of the surface layer is clay loam, followed by clay in the subsequent lower horizons. The bulk density varies from 1.31 to 1.43 Mg m^{-3}, having highest on the surface layer and almost uniform down the depth. The particle density and porespace. varies from 2.65 to 2.78 Mg m^{-3} and 47.0 to 52.9% respectively. Although no regular trend in the particle density values down the profile are observed, the value of pore space increases down the depth. The percentage of coarse sand, fine sand and silt varies from 25.0 to 26.6, 19.0 to 32.6 and 11.8 to 13.8 respectively.

Pedon -2 showed a gradual increase of clay content(Photo plate 2) from the surface down wards and the value ranges from 39.6 to 48.6%. The coarse sand, fine sand and silt ranges from 16.4 to 20.6% 19.6 to 25.6 % and 13.8 to 15.8% respectively. The bulk density was almost uniform with a range of 1.31 to 1.38 Mg m^{-3}. All the layers have clay textural class. The particle density and porespace are more or less uniform throughout the pedon and varied from 2.65 to 2.74 Mg m^{-3} and 49.6 to 51.5%. respectively.

In Pedon-3 similar trend as above, is observed in case of clay percentage (Photo plate 3) which ranges from 31.6 to 44.6. The surface layer has a texture of clay loam whereas, subsurface layers are clayey.The bulk density varied from 1.31 to 1.41 Mg m^{-3} . The particle density and porespace shows a slightly

increasing tendency and ranges from 2.65 to 2.75 Mg m^{-3} and 46.8 to 52.4% respectively. The percentage of coarse sand, finesand and silt varied from 16.6 to 21.6, 21.0 to 39.4 and 11.8 to 16.8 respectively.

Pedon 4 contains maximum percentage of clay amongst all the pedons (Photo plate 4) studied and ranges from 48.6 to 52.6%. All the horizons are of clay textural class. The bulk density and particle density values are almost uniform in different horizons and the porespace percentage ranges from 51.1 to 54.9. The percentage of coarse sand, fine sand and silt ranges from 19.0 to 20.2, 16.4 to 19.0 and 11.8 to 12.8 respectively.

In pedon 5, the lowest percentage of clay content among all the pedons could be observed (Photo plate 5). The value ranges from 18.6 to 32.6% and increase down the depth. All the profiles are clay loam in texture. The bulk density value ranges from 1.25 to 1.38 Mg m^{-3}, Particle density value ranges from 2.65 to 2.74 Mg m^{-3} and porespace varied from 48.9% to 54.4%. The percentage of coarse sand, fine sand and silt range from 21.8 to 39.2, 18.8 to 32.4 and 9.8 to 21.8 respectively.

Considering the physical characteristics of all the pedons described above, it may be seen that there is increases in clay content from the surface to the subsurface horizons. The results have also been depicted in Fig 1. The increase in clay content in the subsurface horizons might be ascribed to process of argillipedoturbation accentuated by deep cracks.

In general the soil texture varies from almost clay loam to clay from the surface downward. The bulk density (B.D) is generally high in vertisol (Murthy *et*

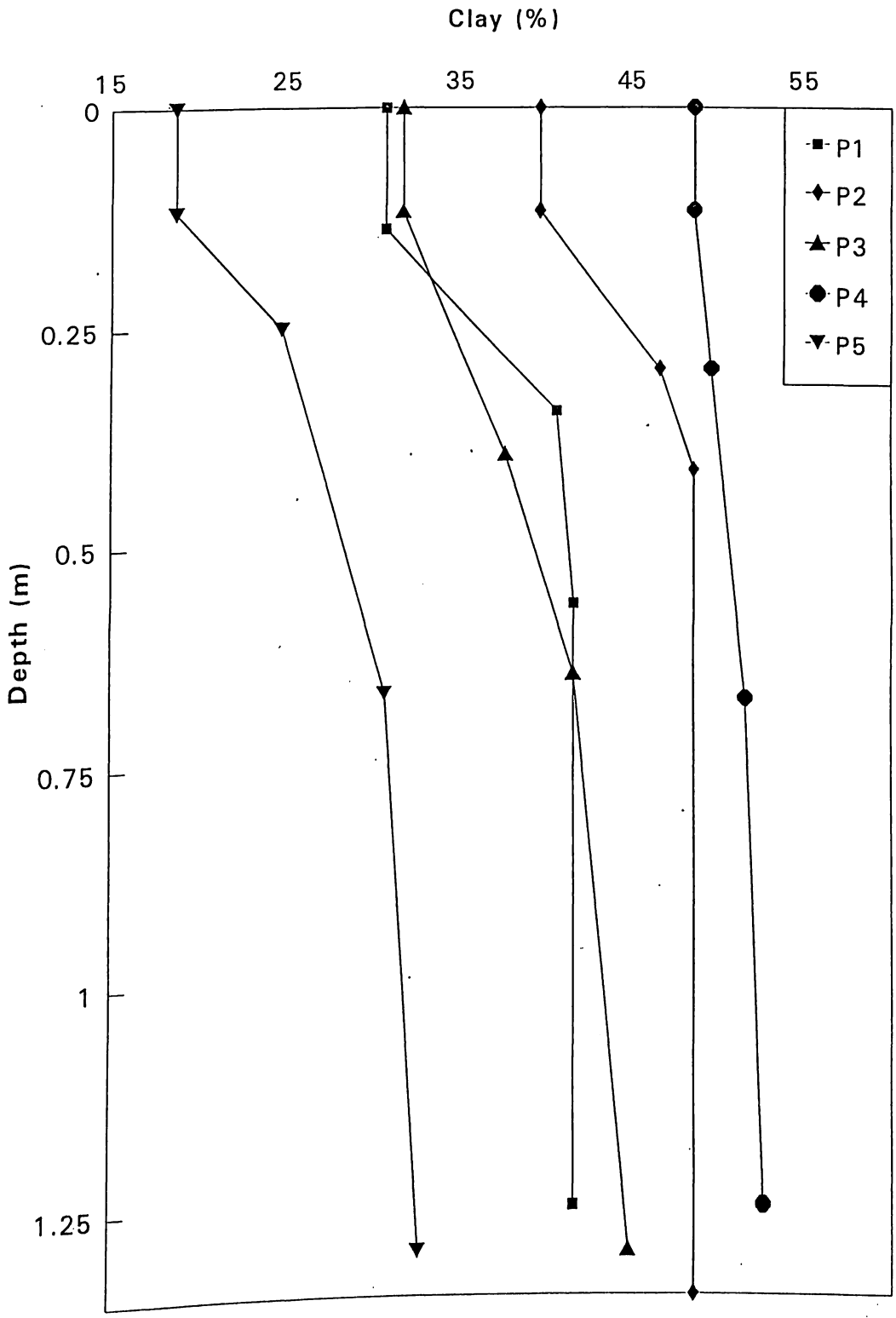


Fig. 1. Vertical distribution of clay vrs. depth

increasing tendency and ranges from 2.65 to 2.75 Mg m^{-3} and 46.8 to 52.4% respectively. The percentage of coarse sand, finesand and silt varied from 16.6 to 21.6, 21.0 to 39.4 and 11.8 to 16.8 respectively.

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Considering the physical characteristics of all the pedons described above, it may be seen that there is increases in clay content from the surface to the subsurface horizons. The results have also been depicted in Fig 1. The increase in clay content in the subsurface horizons might be ascribed to process of argillipedoturbation accentuated by deep cracks.

In general the soil texture varies from almost clay loam to clay from the surface downward. The bulk density (B.D) is generally high in vertisol (Murthy *et*

al., 1982). But Ghildyal and Satyanarayan (1965) are of the opinion that higher B.D. in the soils derived from limestone may be due to higher sand fraction, whereas the high clay content in the soils of chlorite-schist origin might have lowered the B.D. Almost uniform and lower B.D. in the present study might be due to granite -gneiss type of parent material. The particle density(P.D) values vary from 2.65 to 2.78 Mg m^{-3} and the values are almost uniform in different horizon of the pedons.

3. Chemical Characteristics : -

The chemical characteristics of different pedons are presented in Table 4.

All the pedons studied except pedon-4 have soil reaction from neutral to mildly alkaline whereas, pedon 4 is mildly alkaline to moderately alkaline. In all the pedons, there is a gradual increase of pH from the surface downward (Fig. 2) which is in agreement with the work of Arnold and Venkateswarlu (1982) and Murthy *et al.* (1982). Higher pH might be due to higer alkaline earth (Ca,& Mg) content as viewed by Murthy *et al.* (1982). The pH of the adjoining composite soil samples varies from 6.28 to 7.87 which is mildly acidic to moderately alkaline.

The electrical conductivity values are invariably low and it ranges from 0.07 to 0.43 dSm^{-1} in all the pedons.

The organic carbon (O.C.) content on the surface horizon of pedon-4 is the highest (11.9 g kg^{-1}) and a minimum value of 4.1 g kg^{-1} is obtained in pedon-1. There is a decreasing trend in the organic carbon content in all the pedons from the surface downward.(Fig.3). This is in conformity with the work of Hirekurubar *et al.* (1991). The rating for organic carbon in different horizons is low in pedon-1, low to medium in pedon.2,3& 5 and low to high in pedon-4.

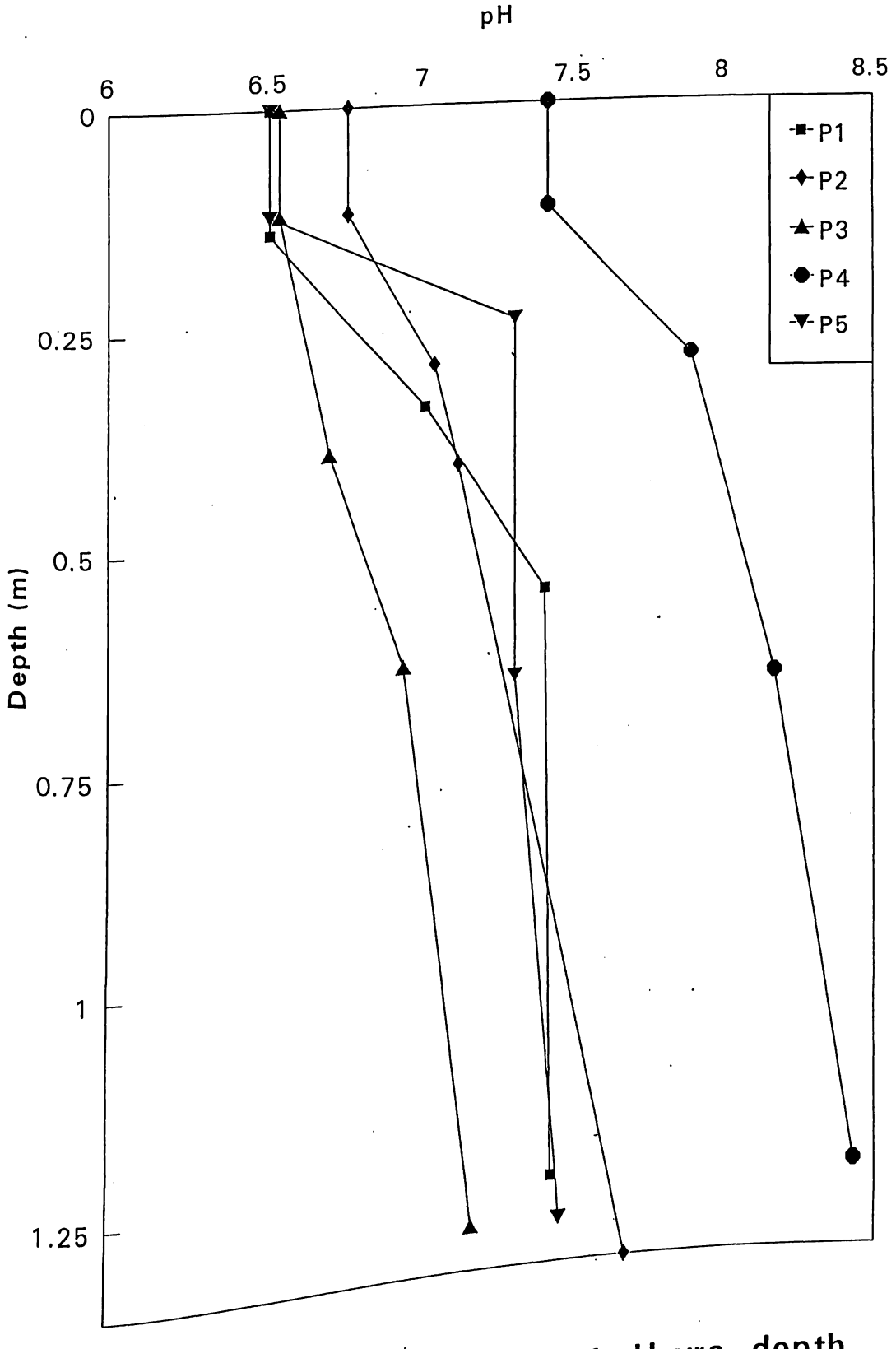


Fig. 2. Vertical distribution of pH vrs. depth

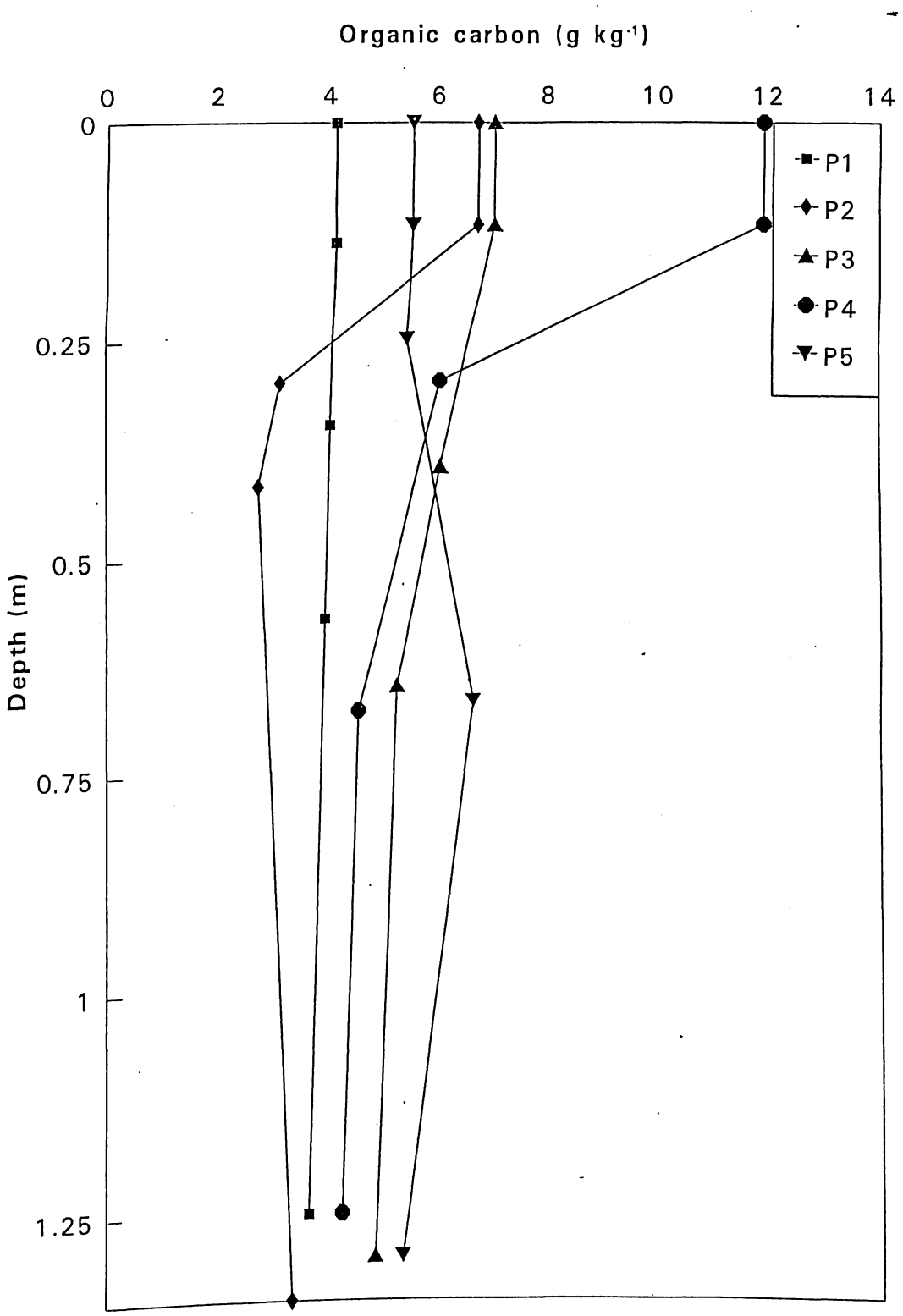


Fig. 3. Vertical distribution of organic carbon vrs. depth

Table 4 Chemical characteristics of pedons

Pedon	Depth (m)	pH (1:2)	E.C. (1:2) (dSm^{-1})	O.C. ($g\ kg^{-1}$)	free $CaCO_3$ ($g\ kg^{-1}$)
1 (A)	0-0.14	6.50	0.15	4.1	10
	0.14-0.35	7.00	0.10	4.0	12
	0.35-0.57	7.40	0.10	3.9	17
	0.57-1.25	7.42	0.13	3.6	22
2 (B)	0-0.12	6.75	0.18	6.7	30
	0.12-0.30	7.03	0.10	3.1	42
	0.30-0.42	7.19	0.13	2.7	50
	0.42-1.35	7.67	0.13	3.3	66
3(D)	0-0.12	6.53	0.18	7.0	16
	0.12-0.40	6.69	0.14	6.0	20
	0.40-0.65	6.93	0.09	5.2	32
	0.65-1.30	7.16	0.12	4.8	57
4 (F)	0-0.12	7.41	0.35	11.9	40
	0.12-0.30	7.89	0.29	6.0	42
	0.30-0.68	8.17	0.39	4.5	50
	0.68-1.25	8.43	0.43	4.2	72
5 (G)	0-0.12	6.50	0.09	5.5	19
	0.12-0.25	7.30	0.07	5.4	22
	0.25-0.67	7.30	0.08	6.6	23
	0.67-1.30	7.45	0.07	5.3	27

The free lime or $CaCO_3$ equivalents content in different horizons of pedons ranged from 10 to 72 g kg^{-1} and showed an increasing trend downwards (Fig.4).In most of the cases $CaCO_3$ content is comparatively low which might be due to granite gneiss type of parent material . The result is in confirmity with the work of Subbaiah and Manickam (1992), on some vertisols of Andhra Pradesh. This might also be due to the fact that the soil samples were collected in the month of February (after the rainy season) and sufficient time was not available for the calcium to go up from the parent material through capillary rise to different horizons .

The Cation Exchange Capacity (C.E.C.) and composition of exchange complex of different horizons of pedons are presented in Table 5. The C.E.C of all the pedons ranges from 13.21 to 34.72 cmol (p^+) kg^{-1}. Pedon 4 has the highest value of C.E.C. and pedon 5 has the lowest value of C.E.C., probably because of the differences in the content of clays.The value generally increases down the depth.(Fig.5).The higher values of C.E.C. in black soils is due to higher 2:1 expanding type of clay minerals.(Tiwari *et. al,* 1989) which is conformed from the high ratio of C.E.C to clay (ranges from 65 - 75 %). Higher ratio of C.E.C./clay could be attributed to the clay minerals to be smectite. C.E.C. in relation to clay content is rather high and this might be due to contribution of clay

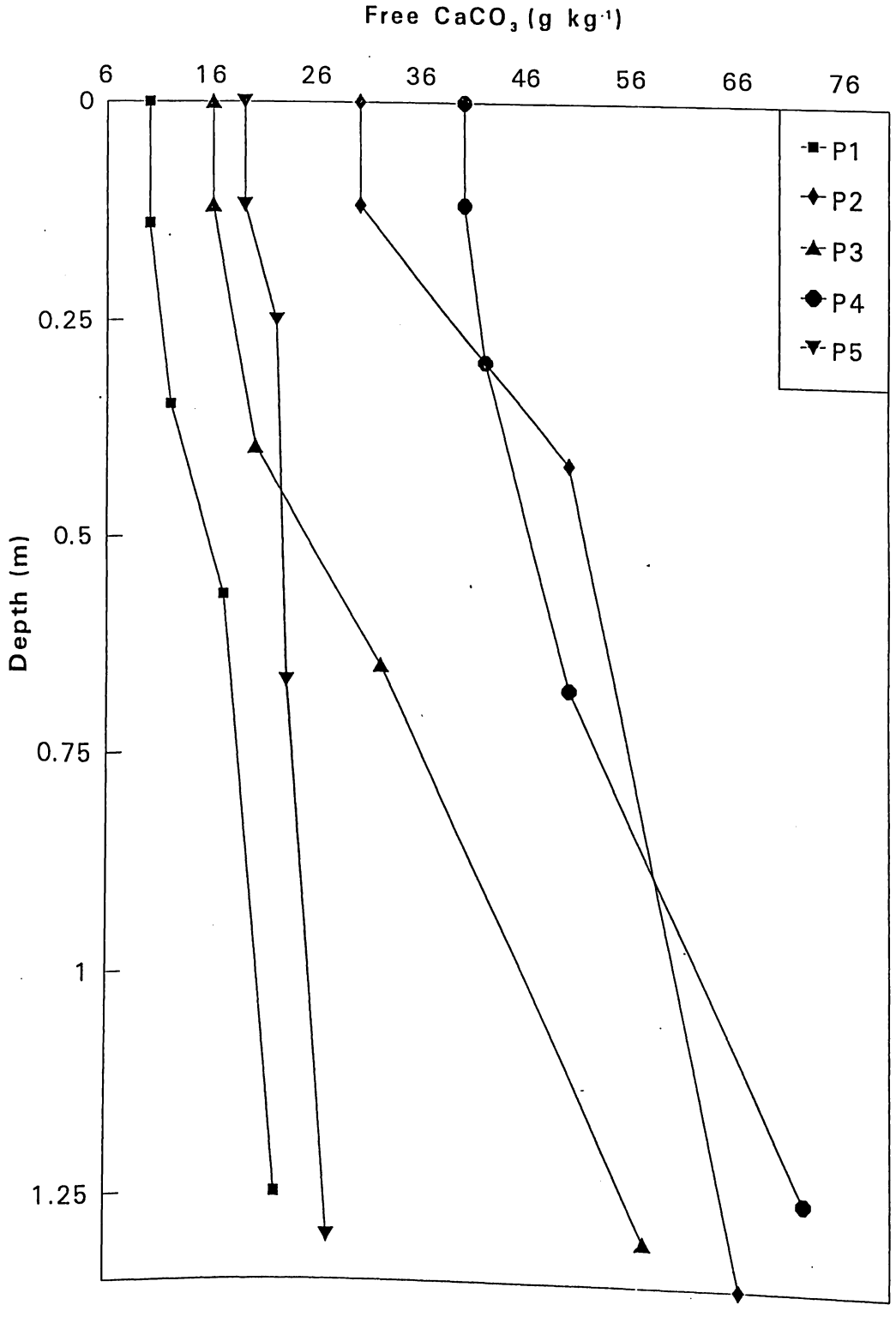


Fig. 4. Vertical distribution of free $CaCO_3$ vrs. depth

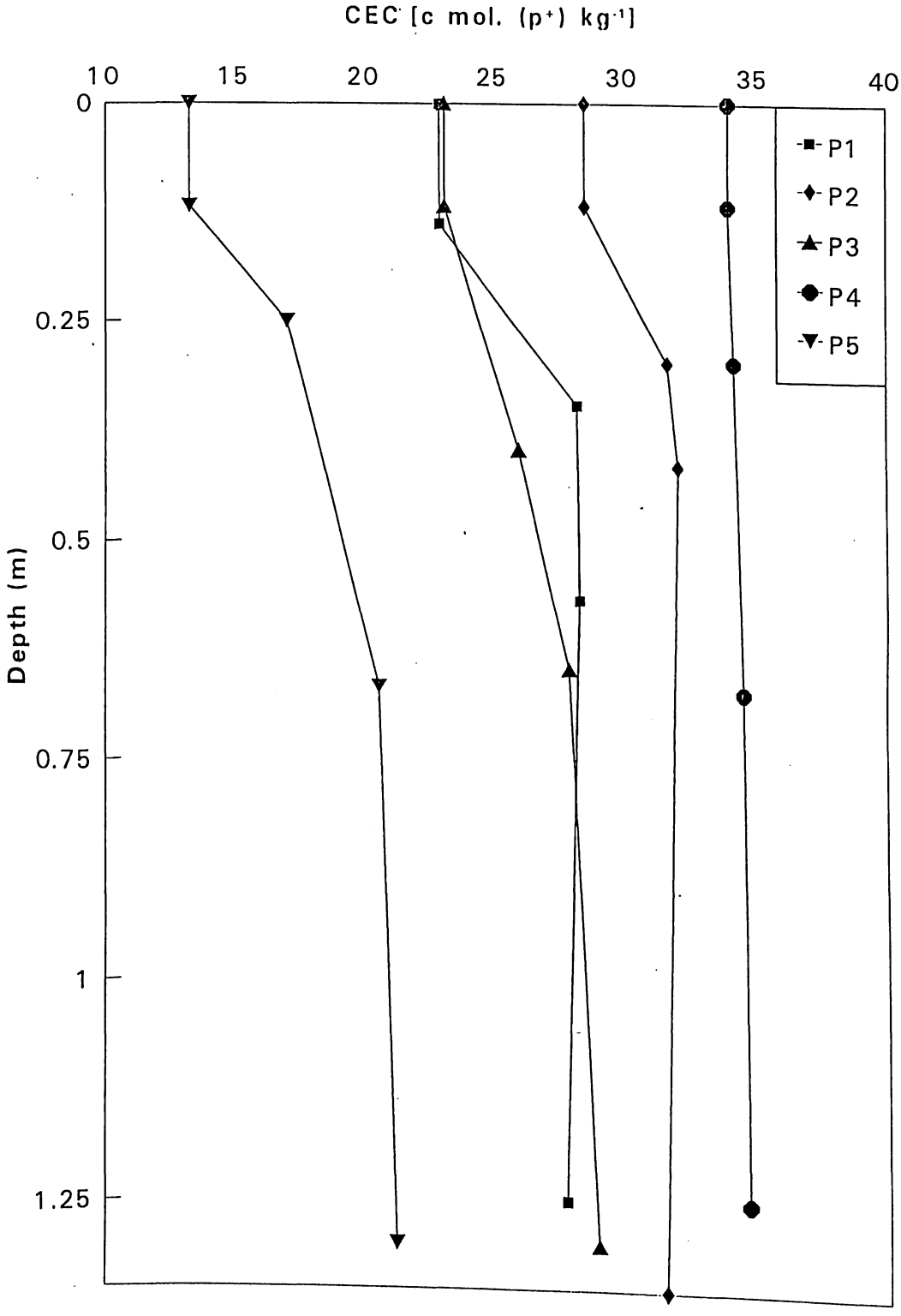


Fig. 5. Vertical distribution of CEC vrs. depth

to C.E.C. of soil as demonstrated in black soils by Satyanarayan *et al.* (1970)and Karale *et al.(*1969). The correlation between C.E.C of soil and percent clay is depicted in Fig.6.The higher values and small variation in C.E.C with depth is again indicative of process of haploidisation as reported by Ray Choudhury *et al.*(1943) and Challa and Gaikward (1986) for heavy soils . From correlation coefficient value (r=0.989**) it may be clearly inferred that there is significant positive correlation between clay and C.E.C in the soil studied . Because the organic carbon content is low, it has no significance to the C.E.C. of soil (r = -0.058).

Considering the composition of exchange complex presented in Table-5 it may be seen that exchangeable Ca^{2+} dominates the exchange complex, followed by exchangeable Mg^{2+}, Na^{+} and K^{+}. In most of the cases exchangeable Ca^{2+} decreases down the depth. But exchangeable Mg^{2+} and Na^{+} increases down the depth. It can be assumed that Na^{+} and Mg^{2+} salts are relatively more soluble than the Ca-salt and leached down the lower layers (Krishnamurthy & Govindarajan, 1977) easily.

All the pedons have high base saturation ranging from 88 to 98 % which indicates that these pedons are highly rich in basic cations.

Table 5 Cation Exchange Capacity and Exchange Composition of pedons

Pedon	Depth (m)	CEC	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	% Base saturation	CEC/Clay %
		[c. mol (p^{+}) kg^{-1}]						
1(A)	0-0.14	22.88	17.92	3.30	0.43	0.39	96	75
	0.14-0.35	28.20	20.90	5.32	0.43	0.80	97	69
	0.35-0.57	28.28	17.61	8.32	0.56	0.74	93	68
	0.57-1.25	27.76	16.87	8.65	0.49	0.91	97	67
2(B)	0-0.12	28.51	19.61	5.98	0.43	0.80	94	72
	0.12-0.30	31.68	19.27	8.64	0.51	0.89	92	68
	0.30-0.42	32.08	18.24	11.31	0.49	1.04	97	66
	0.42-1.35	31.59	17.94	9.97	0.74	0.93	94	65
3(D)	0-0.12	23.07	16.96	4.32	0.49	0.91	98	73
	0.12-0.40	25.94	16.28	6.32	0.43	0.78	92	69
	0.40-0.65	27.87	15.61	9.32	0.51	0.89	94	67
	0.65-1.30	28.99	14.94	11.64	0.61	1.02	97	65
4(F)	0.0-12	34.02	23.54	5.97	0.97	1.6	94	70
	0.12-0.30	34.22	22.04	6.28	0.87	2.6	93	69
	0.30-0.68	34.57	21.32	7.27	0.77	3.5	95	67
	0.68-1.25	34.72	20.08	8.01	0.90	3.9	95	66
5(G)	0-0.12	13.21	7.97	2.33	0.43	0.96	88	71
	0.12-0.25	16.97	10.96	3.2	0.38	1.22	93	69
	0.25-0.67	20.50	12.28	4.65	0.49	1.15	91	67
	0.67-1.30	21.19	11.94	4.52	1.52	1.22	91	65

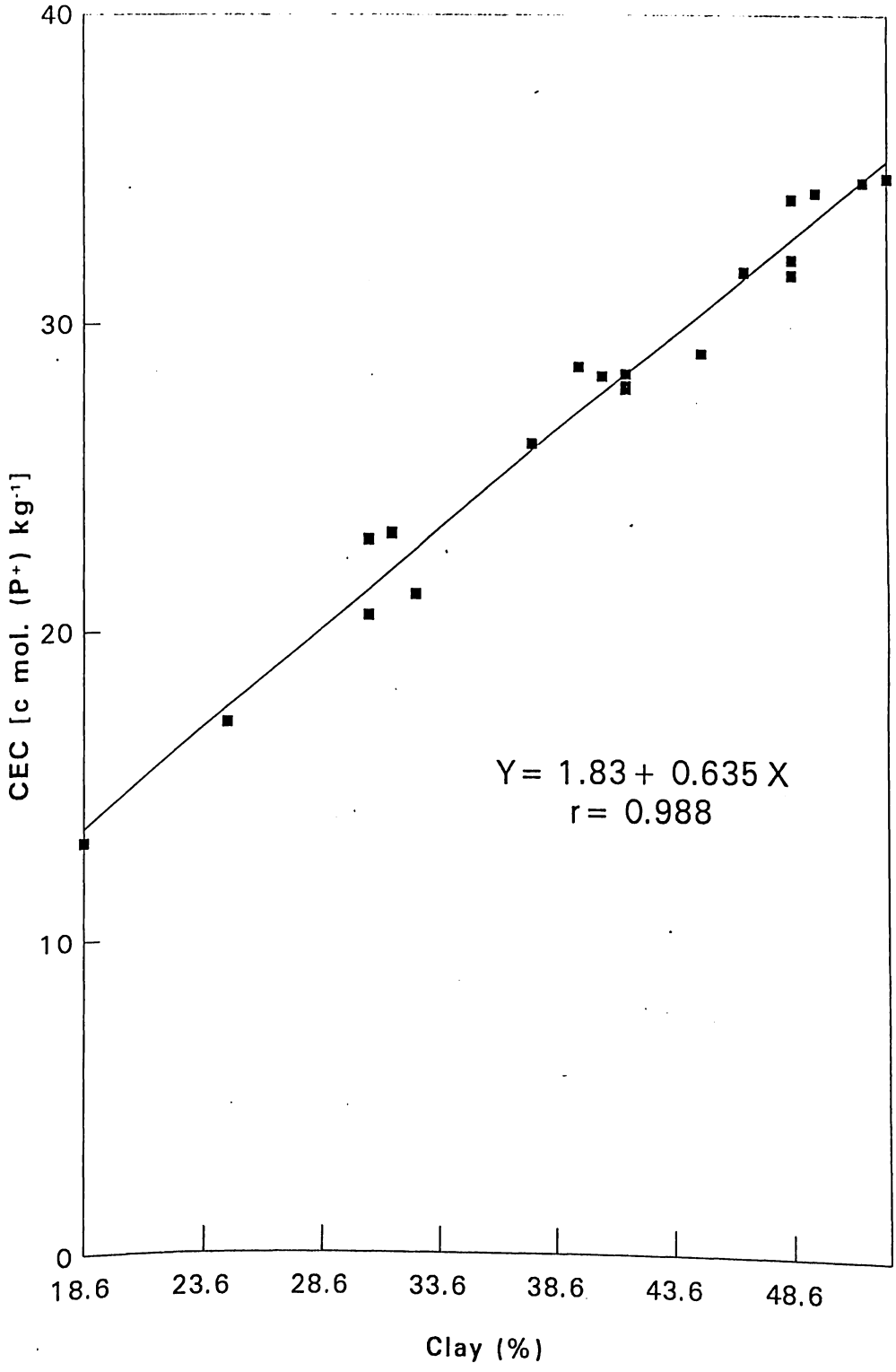


Fig. 6. Correlation between CEC and clay

4. Available Macro-nutrient status of Pedons :

The fertility status of soil indicates the nutrient supplying capacity of a soil to growing crops. This knowledge is a must for successful and economic management of fertilizers and other allied inputs recommended for a crop under an edaphic situation. Hence, horizonwise available nutrient and their status (shown in the parenthesis) for each pedon are presented in Table 6 for N, P, K and S. The change in N, P, K content with depth has been displayed in Fig.7. Although for arable crops, the nutrient status of surface soils are considered for fertilizer recommendation, horizonwise nutrient content would throw some light regarding their subsequent continuous supply to the growing crops., For recommendation of fertilizer depending on soil test values for different crops, the different macro-nutrients are categorized as follows. (Mitra *et al.* 1980).

Major nutrients(kg ha^{-1})	**Low (L)**	**Medium(M)**	**High(H)**
N	<250	250-500	>500
P(Olsen)	<9	9-22	>22
K	<118	118-280	>280

Nitrogen :

The available N status in most of the cases is low, varying from 88.2 to 264.6 kg ha^{-1} and shows a general trend of decreasing down the depth except pedon-5, where the value was more in the subsurface layers. The N status of the composite surface samples is also low (Table - 7).

Table 6 Available Nutrients (macro)status of pedons

Pedon	Depth (m)	N (kg ha^{-1})	P(kg ha^{-1})	K(kg ha^{-1})	S(mg kg^{-1})
1 (A)	0-0.14	264.6(M)	33.1(H)	165.0(M)	12.9(S)
	0.14-0.35	235.2(L)	13.0(M)	240.0(M)	11.2(S)
	0.35-0.57	176.4(L)	10.6(M)	195.0(M)	17.6(S)
	0.57-1.25	88.2(L)	11.0(M)	210.0(M)	17.6(S)
2 (B)	0-0.12	264.6(M)	30.9(H)	210.0(M)	16.9(S)
	0.12-0.30	161.7(L)	14.2(M)	225.0(M)	14.2(S)
	0.30-0.42	132.3(L)	11.8(M)	215.0(M)	18.4(S)
	0.42-1.35	117.6(L)	11.0(M)	215.0(M)	10.8(S)
3(D)	0-0.12	235.2(L)	35.0(H)	190.0(M)	23.3(S)
	0.12-0.40	161.7(L)	17.6(M)	190.0(M)	14.2(S)
	0.40-0.65	176.4(L)	14.2(M)	205.0(M)	11.6(S)
	0.65-1.30	132.3(L)	16.3(M)	230.0(M)	16.8(S)
4 (F)	0.0-12	235.2(L)	20.0(M)	380.0(H)	27.6(S)
	0.12-0.30	176.4(L)	15.2(M)	420.0(H)	15.5(S)
	0.30-0.68	117.6(L)	10.2(M)	340.0(H)	28.5(S)
	0.68-1.25	102.9(L)	9.6(M)	370.0(H)	25.9(S)
5 (G)	0-0.12	176.4(L)	30.9(H)	140.0(M)	15.9(S)
	0.12-0.25	191.1(L)	38.3(H)	170.0(M)	14.2(S)
	0.25-0.67	191.1(L)	25.5(H)	295.0(H)	13.4(S)
	0.67-1.30	197.0(L)	13.3(M)	375.0(H)	23.5(S)

Even though alkaline $KMnO_4$ extractable N is taken as an available N index, recent studies suggest that NO_3-N is a better index of N-availability in vertisol. (Arnold & Venkateswaralu, 1982). Because nitrification is rapid in vertisols, it is to be expected that most of the N added in the form of fertilizers containing NH_4 or NH_2 might be subject to losses by leaching or denitrification within a short time after application. Because some ammonia may be fixed in clay mineral, $Ca(NO_3)_2$ may be more efficient than $(NH_4)_2 SO_4$. NH_4 fixation is expected to be an important factor affecting the efficiency of fertilizer applied to heavy vertisols. It is also reported that there is greater response to fertilizer N in the monsoon than in the post monsoon period.

In vertisols, for an efficient fertilizer N management, it is necessary to consider the following points.

- The NO_3-N status of the soil to a depth of 1m in the soil profile may be important as NO_3-N is significantly correlated to crop production.
- The efficiency of fertilizer N is enhanced by split application for the monsoon crop and deep placement for the post-monsoon crop.
- A system of regular turnover of crop residues would be beneficial, not only in adding N to the low native reserves, but also in improving structure, through *in situ* decomposition.

Phosphorus :

The available P status in most of the horizons is medium to high and the value ranges from 9.6 to 38.3 kg ha^{-1} and shows a decreasing trend down to the lower horizons. The higher value of phosphorus might be due to neutral to mildly alkaline soil reaction. The composite surface samples have also high phosphorus status.(Table 7).

Phosphorus exists mainly in the inorganic form in low humus soils and the amounts present as Ca-Phosphate usually exceed those present as Al-phosphate. Because Ca is the dominant cation in the black soil and the soils are commonly calcareous, added P is usually transformed to Ca-P. Even though applied P does not move from its point of placement within the soil for a heavy textured soil such as vertisols, the physical movement of soil may cause a considerable part of applied P to move i.e. after the soil cracks and starts refilling by movement of adjacent top soil. With later rains, a considerable portion of applied P would move down the cracks. Such movement of P also affects the responses to applied P, both direct and residual.

Olsen's bicarbonate extractable P was found to be the most suitable index in several studies. (Arnold & Venkateswaralu, 1982).

For efficient use of fertilizer P, the following points may be considered.

- To increase recovery of added P, placement in band is necessary.

- In calcareous low land rice soil, an appreciable proportion of P applied may be fixed as the less available carbonoapartite. Hence repeated application of fertilizer P may be recommended.

Potassium :

The available K status was high in pedon-4 and Bw_2, Bw_3 horizons of pedon-5. Although in the rest of the horizons, available K status is medium, the values are on the higher range. No trend is observed when the depth of the pedons is considered. Relatively high K_2O content might be attributed to the granite origin (Subbaiah & Manickam, 1992) of the pedons. In composite surface samples (Table. 7), the available K status is medium in all the pedons except pedon-4 in which the values are high.

The K fixation in vertisol does not appear to be sufficiently severe to cause K to be completely unavailable to plant. However, with alternate wetting and drying and at higher K concentration, part of the exchangeable K is transformed into non-exchangeable forms due to the interstratification of montmorillonitic clay with mica.

The exchangeable K may reflect fairly well the K available to plant, but the correlation with plant uptake may be improved by considering also the soluble K of the saturation extract. Availability seems to be increased with soil moisture.

Responses to applied K are rarely obtained in vertisols. However for efficient use of fertilizer K, the following points may be considered.

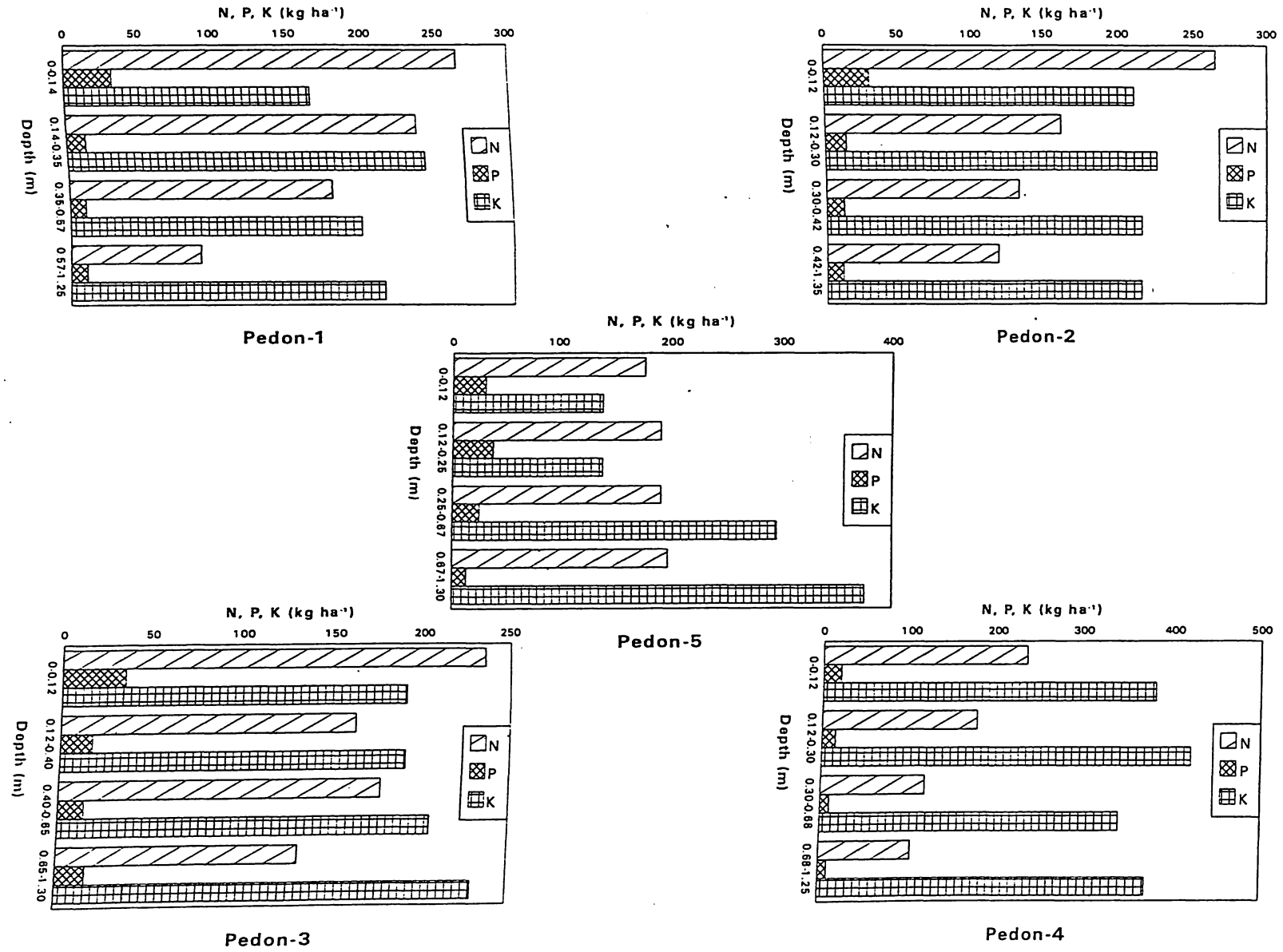


Fig. 7. Vertical distribution of N, P and K vrs. depth.

- Exchangeable K is found to be a good index of K availability in soils.
- About 200 kg ha^{-1} K seems to be the critical limit below which responses to applied K can be expected.
- Fixed K is to be considered as "reserve" K while planning K-fertilization.

Sulphur :

The available sulphur status in different horizons of the pedons varied from 10.8 to 28.5 mg kg^{-1} and no regular trend is observed in different horizons of the pedons. Taking into consideration the critical value of S to the 10 mg kg^{-1} (Mehta *et al.*, 1988) these soils are found to be sufficient in available sulphur.

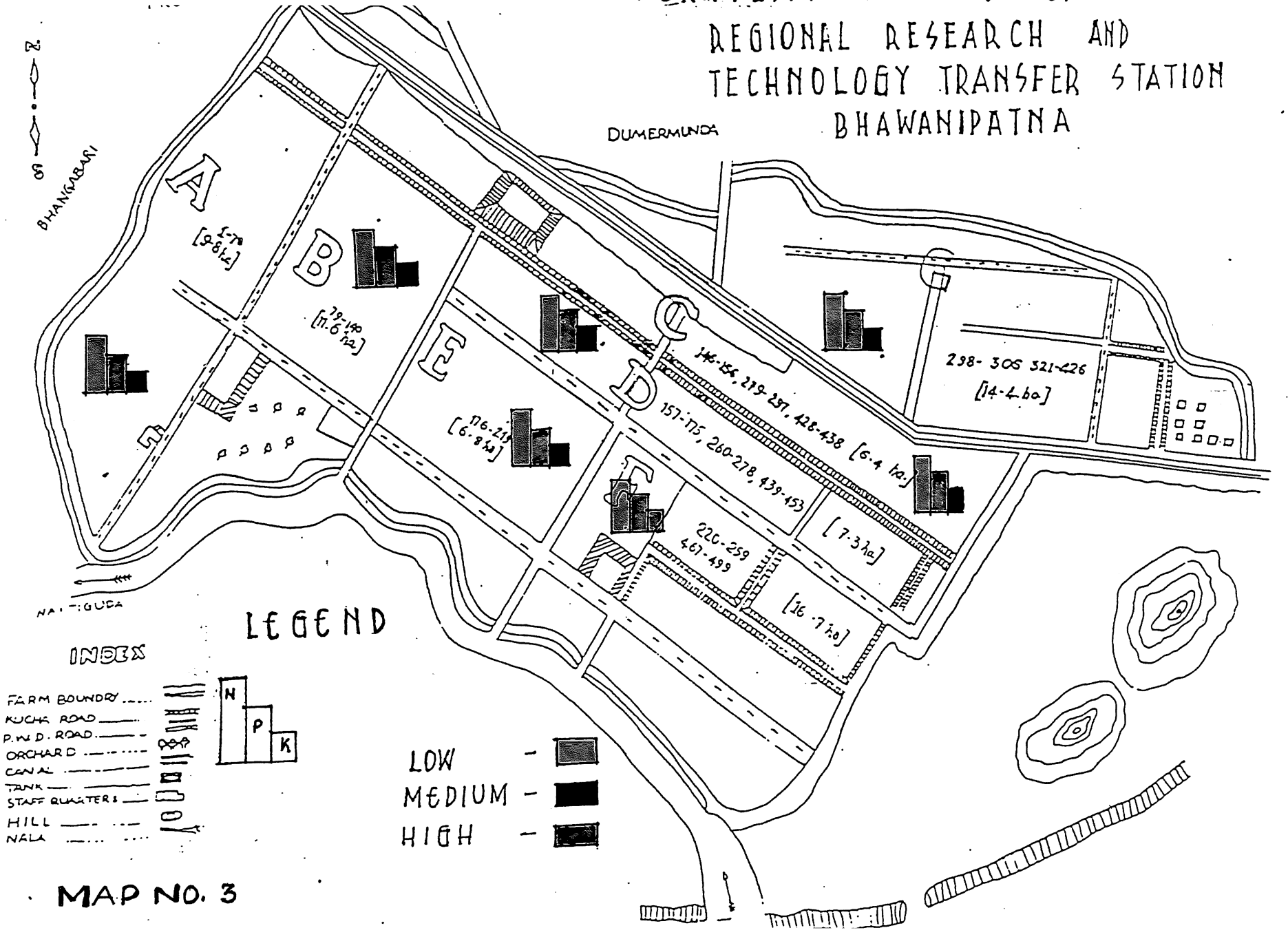
Sulphur is rarely a limiting nutrient in vertisols. The main source of sulphur in vertisol is gypsum in the profile. In many cases, soil organic matter also contributes to the labile-pool of sulphur. Use of sulphur containing fertilizer such as ammonium sulphate or SSP would be useful if the soils are found deficient in sulphur.

Depending on the soil fertility rating (Mitra *et al.,* 1980), the fertility status of RRTTS, Bhawanipatna have been categorised and are presented in Table 7 and soil fertility map has been displayed in Map - 3.

Table 7 **Fertility status of composite surface samples (Available nutrients (kg ha^{-1})**

	pH_w(1:2)	N	P	K
A-1	6.51	221.2(L)	37.2(H)	192.2(M)
A-2	6.55	224.0(L)	39.0(H)	185.0(M)
A-3	6.40	201.6(L)	23.7(H)	148.6(M)
A-4	6.62	229.0(L)	33.0(H)	176.8(M)
A-5	6.46	210.0(L)	28.2(H)	153.4(M)
Mean	6.51	217.2(L)	32.2(H)	171.2(M)
B-1	7.06	215.6(L)	25.7(H)	222.0(M)
B-2	6.85	218.4(L)	30.9(H)	213.2(M)
B-3	6.96	215.6(L)	34.4(H)	209.8(M)
B-4	7.03	228.8(L)	29.8(H)	215.5(M)
B-5	6.86	240.4(L)	30.0(H)	210.0(M)
Mean	6.95	223.6(L)	30.2(H)	214.1(M)
C-1	7.30	226.8(L)	37.9(H)	228.2(M)
C-2	7.27	221.6(L)	31.2(H)	217.5(M)
C-3	6.85	219.6(L)	28.9(H)	211.8(M)
C-4	7.36	248.0(L)	32.3(H)	237.0(M)
C-5	7.23	221.2(L)	30.8(H)	224.6(M)
Mean	7.20	227.4(L)	32.2(H)	223.8(M)
D-1	6.85	217.4(L)	30.8(H)	198.2(M)
D-2	6.76	235.2(L)	35.0(H)	214.4(M)
D-3	6.89	224.0(L)	29.6(H)	238.6(M)
D-4	7.10	212.8(L)	33.5(H)	220.0(M)
D-5	7.19	219.4(L)	29.8(H)	219.8(M)
Mean	6.96	221.7(L)	31.7(H)	218.2(M)
E-1	7.00	235.0(L)	29.8(H)	238.0(M)
E-2	7.19	268.8(L)	31.1(H)	242.2(M)
E-3	6.80	226.8(L)	36.0(H)	229.6(M)
E-4	6.93	221.2(L)	28.8(H)	226.4(M)
E-5	6.85	221.6(L)	30.2(H)	218.8(M)
Mean	6.95	234.7(L)	31.2(H)	231.0(M)
F-1	7.65	234.0(L)	26.2(H)	362.4(H)
F-2	7.40	255.6(L)	30.4(H)	350.8(H)
F-3	7.87	218.4(L)	23.5(H)	374.5(H)
F-4	7.50	229.6(L)	27.1(H)	370.2(H)
F-5	7.62	210.0(L)	24.6(H)	368.6(H)
Mean	7.61	229.5(L)	26.4(H)	365.3(H)
G-1	6.52	216.4(L)	31.1(H)	148.8(M)
G-2	6.53	228.0(L)	32.0(H)	160.0(M)
G-3	6.28	202.4(L)	28.2(H)	154.6(M)
G-4	6.33	208.0(L)	27.8(H)	127.8(M)
G-5	6.45	198.8(L)	29.2(H)	139.9(M)
Mean	6.42	210.7(L)	29.7(H)	146.2(M)

FERTILITY STATUS OF REGIONAL RESEARCH AND TECHNOLOGY TRANSFER STATION BHAWANIPATNA



MAP NO. 3

5. Available micronutrient status of Pedon :

Interest in micronutrient management has increased with introduction of high yielding varieties and scientific management in agriculture . Earlier micronutrients were rarely a serious constraints in growing different crops in traditional methods. Deficiencies of at least one or more micronutrients have been observed in many countries.

Vertisols of neutral to slightly alkaline pH have much in common with regard to micronutrient availability. At low production levels, the supply of available micronutrients is seen to be more than adequate. However, with higher yields or with increased cropping intensity, an increasing number of yield limiting deficiencies through micronutrients may develop.

The following critical limits and methods for assessment of available micronutrients have been suggested by Indian Council of Agriculture Research. (Arnold & Venkateswarlu, 1982).

Nutrient	Method	Average critical values(ppm)
Zinc	DTPA	0.75
Manganese	DTPA	5.00
Copper	DTPA	1.50
Iron	Am.acetate	2.0
Molybdenum	Am.oxalate	0.60

But various authors after intensive research have reported the critical value of micronutrients as follows (Follet & Lindsay, 1970; Berger & Truog, 1940; Prasad & Gajbhiye, 1999).

Nutrient	Method	Average critical values(ppm)
Zinc	DTPA	0.6
Manganese	DTPA	2.0
Copper	DTPA	1.0
Iron	DTPA	4.5
Boron	Hot water extract	0.5

The available micronutrient status of different horizons of the pedons have been presented in Table 8. Moreover, the correlation coefficient of the micronutrient with different soil properties e.g. pH, clay content, C.E.C., $CaCO_3$ and organic carbon have been statistically calculated and are presented in Table 9.

Table 8 Available MICRONUTRIENT status of pedons (mg kg^{-1})

Pedon	Depth (m)	B	Zn	Cu	Fe	Mn
1 (A)	0-0.14	0.28(d)	1.4(s)	2.1(s)	14.8(s)	93.7(s)
	0.14-0.35	1.2(s)	0.5(d)	2.0(s)	6.3(s)	50.4(s)
	0.35-0.57	1.3s)	0.6(s)	1.6(s)	4.8(s)	18.8(s)
	0.57-1.25	1.6(s)	0.5(d)	0.8(d)	2.8(d)	15.8(s)
2 (B)	0-0.12	0.66(s)	1.4(s)	4.0(s)	17.2(s)	54.6(s)
	0.12-0.30	1.14(s)	0.9(s)	2.1(s)	4.0(s)	20.6(s)
	0.30-0.42	0.17(d)	0.7(s)	0.8 (d)	1.2(d)	4.5(s)
	0.42-1.35	0.06(d)	0.6(s)	0.4 (d)	0.8(d)	4.4(s)
3(D)	0-0.12	0.17(d)	1.4(s)	3.8(s)	20.7(s)	46.5(s)
	0.12-0.40	0.42(d)	1.2(s)	3.1(s)	6.3(s)	32.0(s)
	0.40-0.65	2.46(s)	1.1(s)	2.7(s)	3.7(d)	15.3(s)
	0.65-1.30	2.34(s)	1.0(s)	1.8(s)	3.6(d)	13.2(s)
4 (F)	0.0-12	0.56(s)	1.2(s)	5.5(s)	15.3(s)	27.7(s)
	0.12-0.30	1.12(s)	0.7(s)	2.7(s)	5.8(s)	11.0(s)
	0.30-0.68	0.98(s)	0.5(d)	0.9(d)	0.7(d)	5.6(s)
	0.68-1.25	0.82(s)	0.5(d)	0.4(d)	0.5(d)	4.3(s)
5 (G)	0-0.12	0.54(s)	1.7(s)	3.5(s)	25.0(s)	44.1(s)
	0.12-0.25	1.4(s)	1.4(s)	3.0(s)	19.4(s)	37.8(s)
	0.25-0.67	0.66(s)	1.2(s)	2.3(s)	7.8(s)	24.7(s)
	0.67-1.30	0.32(d)	1.1(s)	0.8(d)	3.0(d)	5.3(s)

Zinc :

Available Zn in these soils varied from 0.5 to 1.7 mg kg^{-1}. Considering 0.6 mg kg^{-1} Zn as the critical value, the surface layers are well supplied with Zn. Almost all the subsurface layers are also sufficient in available Zn. Its availability shows a decreasing trend with depth. Highest level of Zn content in the surface layers of the profile might have been due to their regular addition through plant residues on the surface. (Tiwari & Mishra, 1990). It is significantly and negatively correlated with clay (r= -0.776*), pH (r = -0.71**), $CaCO_3$ (r = 0.476*) and C.E.C. (r = - 0.726**) and positively correlated with organic carbon (r = 0.495*)(Table-9).

Manganese :

Available Mn ranges from 4.3 to 93.7 mg kg^{-1}. These wide variation were due to degree of weathering, topography, cropping intensity etc. In general available Mn in the surface layer are higher which gradually decreased with depth. Higher concentration of Mn at the surface layer might be due to higher biological activity in the surface soil (Murthy *et al.*, 1997). Considering the critical value of Mn to be 2.0 ppm it may be inferred that these soils are sufficiently supplied with Mn. The available Mn is significantly correlated with clay (r=0.583**), pH (r = - 0.731*), $CaCO_3$(r = -0.682**) and CEC (r = -0.473*). But no correlation could be obtained for organic carbon (Table.9).

Copper :

Available Cu in these soils varied from 0.4 to 5.5 mg kg^{-1}, which shows that almost all the pedons are sufficiently supplied with Cu considering 1 mg kg^{-1} as the critical level. It also shows a decreasing trend with depth. The higher available Cu at the surface might be due to higher organic carbon content at the surface. It is significantly correlated with pH (r = -0.519*) and organic carbon (r =

n 826**). No significant correlation could be obtained for other soil properties (Table 9).

Iron :

Available Fe ranged from 0.5 to 25.0 mg kg^{-1} among the pedons, the value of which decreased with depth. Relatively higher amount of available Fe in the surface layers might be due to adequate supply of this nutrient and almost neutral pH. Comparatively lesser available Fe in the subsurface horizons might be due to alkaline conditions in which Fe^{2+} is transformed to non-available form. Coefficient of correlation between available Fe and soil properties (Table 9) indicated that it is significantly correlated with organic carbon (r = 0.516*), pH (r = - 0.621**), clay (r = -0.733**), $CaCO_3$(r = 0.551**) and CEC (r = -0.650**)

Boron :

The value of D.T.P.A. extractable boron has been presented in Table 8. The value ranges from 0.17 to 2.46 mg kg^{-1} and generally increased in the sub-surface layers. The surface soils are either deficient or marginally sufficient with boron taking 0.5 ppm as the critical value. But the boron deficiency does not occur probably because of the accumulation of soluble boron in the sub-soil. Coefficient of correlation among B and soil properties indicated that it has no significance with any of the soil properties.

Table 9 : Correlation coefficient of micronutrients with soil properties

	Zn	Cu	Fe	Mn	B
Clay	-0.776**	0.343	-0.733**	-0.583**	0.017
pH	-0.718**	-0.519*	-0.621**	-0.731**	0.113
O.C	0.495*	0.826**	0.516*	0.181	-0.136
$CaCO_3$	-0.476*	-0.410	0.551*	-0.682**	0.049
C.E.C.	-0.726**	-0.243	-0.650**	-0.473*	0.113

N.B.: * significant at 1 % level ** significant at 5 % level.

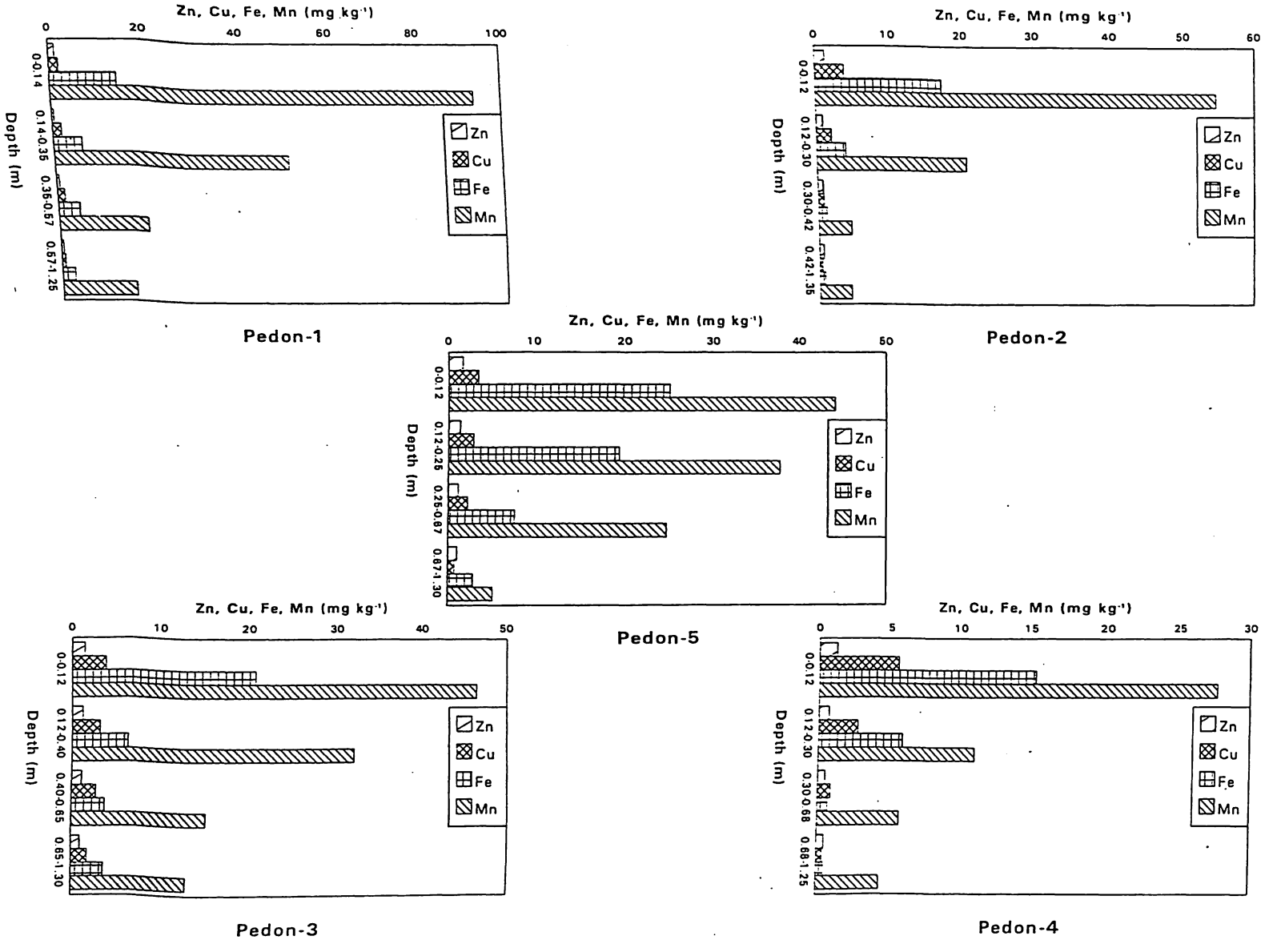


Fig. 8. Vertical distribution of Zn, Cu, Fe and Mn vrs. depth.

6. Soil genesis :

Soil genesis proceed with the break down and alteration of primary minerals constituting the rocks. The genesis of the parent material involves weathering process, geochemical changes and the migration of soluble colloidal and solid rocks and soil constituents. The origin of parent materials in which vertisols have developed are the black soils in the lower lying sites. Depending on parent rocks and environmental conditions, vertisols occupy only the lowest land scape position, or in addition lower foot-slopes and gently sloping hill sites.

Vertisols develop from a variety of rocks and sedimentary material under conditions that favour weathering, but restrict leaching. Environmental conditions that favour vertisol formation are that the rainfall should be sufficient to enable weathering, but not so excessive as to make smectite unstable. Moreover, there should be dry period to enable crystallisation of clay minerals.

The geological formation in north-western portion of the Western undulating Zone consists mainly of Vindhyan quartzite, shale and shally lime stone. The central plain portion has geological deposit of granite-gneiss rocks (Annonymous, 1988-89).

While traversing in the Western Undulating Zone, red and laterite soils were found on crest and upper slope positions and black soils in the low lying sites. The RRTTS, Bhawanipatna is divided into 2 main parts through the Bhawanipatna-Khariar road. On the right side of the road, nearing to the RRTTS, office are mid upland to mid medium land situations. On the left side of the road , it is mostly mid lowland situations. The entire research station may be considered as a valley plain land and different hills and hillocks surround this research stations.

The mineralogy of fine sand fractions and composition of parent rock as has been reported by Sahu *et al.,* (1990) for the same locality is presented below.

Mineralogy of fine sand fractions of RRS, Bhawanipatna (Arkabali)

Constituents	**Depth 22-95 cm**	**Depth 125 - 150 cm**
Quartz	56.55	57.88
Orthoclase	12.39	18.02
Plagioclase	2.69	10.92
Ilmenite	14.87	7.10
Garnet	2.13	1.09
Zircon	1.94	0.54
Sillimanite	5.82	1.09
Mica and other silicates	2.72	3.28

Considering the above table, the parent rock constitute mostly basic granulite, pyroxine etc., which are mostly rich in basic cations. Presence of higher amount of plagioclase feldspar in the sub-soil indicated low intensity of weathering.

Basic rocks have large quantities of weatherable minerals and rock weathering produces a clay rich soil. Because of the restricted drainage and slow to very slow permeability, the feldspar and ferromagnesian minerals provide basic ionic environment giving rise to smectite as the dominant clay minerals and subsequently vertisols.

From the morphological studies of the pedon 1, 2, 3 and 4 , no distinct horizons could be recognised based on colour, texture, structure etc. The profiles are very dark gray on the surface successively grading to a lighter shade in the

C horizon. This indicated greater reducing condition in the upper horizon and concentration of free lime in the lower horizons. Moreover, uniformity in horizon differentiation might be due to hoploidization by argillipedoturbation. This might be the reason for no characteristic development of B-horizon and A-C profiles are met with. The black colouration in these soils might not be due to organic matter content (as it is low) but might be due to titaniferous magnetite (FeO TiO_2-14.87) and some calcium-humate formation. Wide cracks of more than 3 cm , although seen in summer months, it was not observed during profile study as it was in the month of February. Similarly bigger size lime concretions in the lower horizons could not be observed because of untimely rainfall and less time available for desiccation . Considering the above properties, these pedons could be placed under the order **Vertisols.**

In case of pedon 5, the soils have developed in mid upland to mid medium land situation. The soils are moderately well drained and so the surface texture is sandy loam. Crack development is not so prominent on the surface, although 1-2 cm wide cracks are observed throughout the pedon. There is development of cambic horizon which is mostly due to texture , structure and development of Fe, Mn concretion. Hence, these soils are placed under the order Inceptisols. But in the lower horizons, lime concretions, wedged shaped aggregates and slickensides are observed inferring thereby that these soils are intergrading towards vertisols.

7. Soil Classification :

Classification is a grouping of soils into catagories, based on soil morphology. Classification of soil into groups having similar forms and appearance (taxonomy) allows.

i) to deduce some properties about all other soils in that class or group.

ii) to help in the study of variation that exhibits and the climatic and topographic environments where certain soil properties will be expected. The expected problems of a soil, because of climate, relief, or geologic origin, help explain some reduction in plant growth and other uses and the likely methods of correlation.

Soil classification is being an important aspects of soil survey, in the present investigation, an attempts have been made to classify the soils of RRTTS, Bhawanipatna as per Soil Survey Staff (1975), Soil Taxonomy and Soil Survey Staff (1998), Keys to Soil Taxonomy and are concisely presented in Table 10.

The soils of Pedon 1, 2, 3 and 4 which is proposed to be Bhawanipatna-1(Bpt 1) series and are placed under the order **Vertisols**, because they

i) do not have a lithic or paralithic contact, petrocalcic horizon, or duripan within 50 cm of soil surface and

ii) slickensides from a depth of 15 cm to > 100 cm and wedge shaped peds and

iii) a weighted average of 30 % or more clay in the fine earth fraction throughout the pedon (> 1.25m)

iv) have cracks (more than 1 cm wide) that open and close periodically and extend upto more than 50 cm depth and

v) have gilgai microrelief on the surface.

These pedons are placed under suborder "**Usterts**", because, cracks in these pedons open for more than 90 cumulative days upto more than 50 cm depth and close for 60 consecutive days.

The above pedons are grouped under great group "**Haplusterts**" because, they do not have salic, or gypsic or calcic or petrocalcic horizon within 100 cm of mineral soil surface and pH value of more than 5.0.

Pedons 1, 2 and 3 covering A, B and D block respectively are placed under subgroup "**Chromic Haplusterts**" because, within 30 cm of mineral soil surface, 50 % or more colours have a colour value moist of 4 or more.

In the family level, the above pedon are placed as Fine, smectitic, hyperthermic, **Chromic Haplusterts**.

But Pedon 4 covering the area of F and E block satisfies all the requirement to be placed under "**Typic Haplusterts**" sub groups.

In the family level, they are placed under Fine, smectitic, hyperthermic **Typic Haplusterts**.

Pedon 5 covering the area of G-block is proposed to be Bhawanipatna-2 (Bpt 2) series and are placed under the order **"Inceptisols",** because they

i) have a cambic horizon and also an ochric epipedon.

ii) do not have a spodic , argillic, natric or oxic horizon.

iii) do not have plinthite, placic horizon, and salic horizon within 75 cm of soil surface.

iv) cracks that are 1 cm or more wide at a depth of 50cm or more and that opens to the base of Ap horizon or to the surface.

These are placed under suborder "**Ustepts**", because they have an ustic soil moisture regime because of its mean annual soil temperature of more than 22°C and is dry in some or all parts for more than 90 cumulative days.

They are placed under the great group "**Haplustepts**" because

i) they do not have a duripan within 100 cm of mineral soil surface

ii) do not have calcic or petrocalcic horizon and

Iiii) have free CO_3 within 125 cm and a base saturation (by NH_4OAc) of more than 60 % in all the horizons.

They are placed under subgroup **"Vertic Haplustepts"** because they have cracks within 125 cm of the mineral soil surface that are more than 5 mm wide, and have slickensides and wedge shaped aggregates within 125 cm of the mineral soil surface and are more than 15 cm thick.

In the family level, it is placed as Fine loamy, smectitic, hyperthermic **Vertic Haplustepts.**

In the family differencea, 3 aspects namely particle size class, mineralogy class and soil temperature class were considered. Particle size classes, were determined taking weighted average of clay and fine sand in the control section into consideration. Although in the present study the mineralogy of clay fractions have not been determined but taking percentage of CEC/clay ratio (65 - 75 %) and the findings of Sahu *et al.* (1990) for the soils of the same locality, the dominance of smectite clay minerals in these soils is inferred.

The average annual soil temperature is more than 22°C and the difference between MWST and MSST is more than 5°C for which these soils are placed under hyperthemic temperature class.

Table 10. Taxonomic classification of soils

Pedon No.	Blocks covered	Series	Order	Suborder	Great group	Subgroup	Family
1.	A	Bpt - 1	Vertisols	*Usterts*	*Haplusterts*	*Chromic Haplusterts*	Fine, smectitic, hyperthermic *Chromic Haplusterts*
2.	B	Bpt - 1	Vertisols	*Usterts*	*Haplusterts*	*Chromic Haplusterts*	Fine, smectitic, hyperthermic *Chromic Haplusterts*
3.	D	Bpt - 1	Vertisols	*Usterts*	*Haplusterts*	*Chromic Haplusterts*	Fine, smectitic, hyperthermic *Chromic Haplusterts*
4.	F	Bpt - 1	Vertisols	*Usterts*	*Haplusterts*	*Typic Haplusterts*	Fine, smectitic, hyperthermic *Typic Haplusterts*
5.	G	Bpt - 2	Inceptisols	*Ustepts*	*Haplustepts*	*Vertic Haplustepts*	Fine loamy, smectitic, hyperthermic *Vertic Haplustepts*

CHAPTER - V

SUMMARY AND CONCLUSION

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SUMMARY

A detail soil survey was conducted in different blocks of Regional Research and Technology Transfer Station, (RRTTS), Bhawanipatna under O.U.A.T., Bhubaneswar. Five pedons from different physiographic situations belonging to different blocks were studied, characterised and classified.

The study area has been placed under Western Undulating Agroclimatic Zone of Orissa having hot and moist sub-humid climate. The research station is situated on 19.58 ^{0} N latitude and 83.12 ^{0} E longitude and develop on granite-gneiss parent material with an average rainfall of 1354 mm.

Morphological characteristics were studied in the field during 17th and 18th February, 2000. The laboratory analysis include physical characteristics like mechanical composition, bulk density, particle density, and chemical characteristics like pH, E.C., organic carbon, C.E.C. and exchange composition, free $CaCO_3$, available N, P, K, S, Fe, Mn, Zn, B and Cu.

The soils were classified as per Soil Taxonomy (Soil Survey Staff, 1975). On the basis of this classification, two orders were recognised.

Depending on these soil orders, two soil series were categorised as Bpt-1 and Bpt-2. Soil properties and other characteristics are summerised on the basis of soil series as under :

1. The soil colour on the surface of Bpt-1 series is dark grey brown to light brownish gray and that of Bpt-2 series is pale brown on the surface. Similarly the subsurface horizons of Bpt-2 series, the soil colour is very dark grey brown to brown and for Bpt-1 it is dark gray brown to dark brown.

2. All the pedons in both the series are very deep and parent material could be observed in some cases below 1.25 m depth. The surface texture of Bpt-2 is sandy loam which grades to clayloam downwards. In case of Bpt-1, the surface soil texture is clay loam to clay, but the subsoil layers are completely clayey in texture.

3. Wide (2-3 cm) and deep cracks are observed in all the pedons of Bpt-1 series, and it extends upto 1m or more. But in Bpt-2, the width of surface cracks are comparatively less (1-2 cm).

4. The soil structure of surface samples are mostly subangular blocky to granular , but in subsurface layer, strong , coarse, angular blocky structure are met with in all the pedons.

5. Soil consistency in all cases are hard to very hard, very firm, very sticky and plastic.

6. In the subsurface layers of all the pedons, slickensides with shiny pressure faces and wedge shaped aggregates are observed, confirming to the process of argilli-pedoturbation in the pedons.

7. Irregular Fe, Mn concretion of 1-2 mm size are observed in both the subsurface and subsoil horizons in all the pedons and lime concretions are observed mostly in the subsoil horizons in all the pedons.

8. Soil reaction in all the pedons vary from slightly acidic to neutral on the surface to moderately alkaline in the subsoil horizons. There is gradual increase of pH from the surface downwards in all the cases.

9. The electrical conductivity values are very low indicating no accumulation of soluble salts.

10. In general, the level of organic carbon is medium on the surface and low in the bottom layers and the value decreases down the depth.

11. The content of free $CaCO_3$ is comparatively low on the surface and the value increases down the depth.

12. The C.E.C. values of soils in Bpt-1 series are higher in general and the value increases with depth. Comparatively lower C.E.C. values are obtained for Bpt-2, although the value increases with depth. A positive significant correlation between clay and C.E.C. could be obtained inferring thereby that the CEC of soils are mainly governed by the amount of clay present.

13. In all the pedons the exchange complex is dominated by Ca^{2+}, followed by Mg^{2+}, Na^{+} and K^{+}.

14. There is almost little variation in the percentage base saturation values in different horizons of pedons and it varies from 88 to 98.

15. Much higher value of CEC/clay percent is obtained in all the pedons (65-75) inferring thereby that the clay minerals are dominated by smectites.

16. Considering the available major nutrient status of soils, it is seen that the available N in surface layers of all the pedons in Bpt-1 is more and the value decreases with depth. But incase of Bpt-2, the value is low on the

surface and it increases downward. In general the available nutrient status is low in all the horizons. Similarly available P (Olsen) content is high on the surface in al most all the pedons of Bpt-1 and it is medium in the subsurface layers. But in case of Bpt-2, the available P is rated as high upto a depth of 0.67 m and then it is medium. Available K content is medium in all the layers of pedons 1, 2 and 3 and high in pedon 4 under Bpt-1 series. But in Bpt-2 series, the value is medium on the surface and subsurface horizons and high in the lower horizons. Available S content in all the horizons of both the series is sufficient and the content varies from 10.8 to 28.5 mg kg^{-1}. The available nutrient status of the composite soil samples are rated as low, high and medium for N, P and K respectively and fertility map has been prepared accordingly.

17. The available micronutrient status of pedons indicated that available B is sufficient in all the pedons excepting pedon-3 and surface horizon of Pedon 1. Available Zn, Cu, Fe and Mn in almost all the pedons are rated as sufficient indicating thereby that these soils are sufficiently enriched with the above micronutrients.

18. As per Soil Taxonomy, Bpt 1 series has been classified as *Typic/Chromic Haplusterts* and Bpt-2 series as *Vertic Haplustepts*.

CONCLUSION

1. The RRTTS, Bhawanipatna is situated on an undulating terraced mid-upland and mid-lowland, and imperfectly to moderately well drained. The parent rock is granite-gneiss, basic granulite and charnokites, with pyroxines. There is an appreciable content of free carbonates and free oxides. There are gilgai micro relief, wide cracks on the surface and slickensides in the subsurface layers.
2. The soil texture are mostly clayey which pose problem for cultivation. To get optimum tilth, tillage operation should be done at right moisture consistency.
3. As the organic matter content is low, application of organic manure/green manure helps in water infiltration rates and physical condition of the soil. Incorporation of rice straw, sawdust, molasses etc., for improving aggregability of such soils has proved beneficial.
4. The beneficial effects of vertisols and their associated vertic subgroups like favourable surface structure, deeper solum, high water-retentive capacity high cation exchange capacity etc., could be better achieved by adopting improved soil water and crop management practices.
5. In the research station, the rainfed agriculture is mostly followed and the main source of available water is rain. Due to poor infiltration characteristics; run off, erosion and waterlogging are the serious problems encountered during the rainy season. Use of the natural topography and drainage patterns might solve the problem to a greater extent.
6. These soils are not suitable for intensive irrigated agriculture as it may result in a high water table, deteriotion of water quality and salinisation.

Economic and profitable irrigated agriculture can be practised if proper drainage facilities are provided and an adjudged quantum of irrigation water is released according to the intake rate.

7. For any cropping system, the following components may produce better results

i) Land and rain water management using watershed concept and graded broad bed and furrow system to reduce run off and soil erosion. The run off can be harvested in a tank and then recycled for supplemental live saving irrigation.

ii) In dry season, primary tillage is a necessary operational step in the efficient management of vertisols. Primary tillage operations can be carried out more easily just after the harvest of the crop with residual moisture.

iii) Dry sowing in vertisols is recommended and sequential cropping or intercropping system with legume may be adopted.

During application of fertilizers, the following ~~instructions~~ suggestions may be considered.

i) Nitrogeneous fertilizers containing NO_3 are more efficient than NH_4 or NH_2 forms.

ii) The efficiency of fertilizer N is enhanced by split application for the monsoon crop and deep placement for the post monsoon crop.

iii) A system of regular turnover of crop residues would be beneficial, not only in adding N to the low native reserves, but also in improving structure through *in situ* decomposition.

iv) To increase the recovery of added P placement in band is necessary.

v) In calcareous low land rice soils, an appreciable proportion of the P applied may be fixed as the less available carbonoapatite, hence, repeated application of fertilizer P may be required.

vi) The availability of K is usually sufficient in vertisols. But if the available K content is less than 200 kg ha^{-1}, response to applied K can be expected.

9. The cropping system to be adopted for the RRTTS, Bhawanipatna may be as follows.

a) **Rainfed**

Single cropping system	**Double cropping system**
(Kharif)	(Kharif - Rabi)
Rice	Rice - horsegram
Maize	Minor millet-horsegram/ niger/mustard
Groundnut/blackgram/ arhar/ragi/sesamum	Groundnut-horsegram/linseed/ gram/khesari Maize-mustard/niger

b) **Irrigated (Kharif-Rabi)**

Rice - wheat	Rice - vegetable
Rice - rice	Vegetable-vegetable Sugarcane

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BIBLIOGRAPHY

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Abtahi, Ali (1980). Soil genesis as affected by topography and time in calcarous parent material under semiarid condition in Iran. *Soil Sci.Soc. Am.J.* **44**: 329-335.

Ahuja, R.L.; Garalapuri, V.N.; Manchanda, M.L. and Khanna, S.S. (1978). Physiography and soil associations of Haryana. *J. Indian Soc. Soil Sci.* **26** : 261-267.

Anitha, G.; Bhanuprasad, V.; Verraiah, K and Pillai, R.N. (1998). Morphology and classification of black soils of Gurazala Mandal in Guntur district of Andhra Pradesh. *The Andhra Agril. J.* **45** (1&2) : 55-60.

Annonymous, (1988-89). *Status report on Agril. Res. and Extn.,*Western Undulating Zone., R.R.S. Bhawanipatna.

Arnold, F. and Venkateswaralu, J. (1982). Chemical properties and fertility management of vertisols. Symposia Paper-II, *12th International Congress of Soil Science,* New Delhi.

Bal, D.V. (1993) : Soils of Central provinces and Berar. *Indian Soc. Soil Sci. Bull* No-**2.**

Basu, J.K. (1942) As quoted by Raychoudhury (1963) in "Black Soils of India."

Berger amd Truog (1940). *J. Am. Soc. Agron, 32, 297.*

Bharamabe, P.R.I.; Kadam, S.G.; Shinde, S.D. and Shelke, D.K. (1999). *J. Indian Soc. Soil Sci.* **47 (4)** : 749-754.

Bhattacharjee , J.C.; Landey,R.J. and Kalbande, A.R. (1977). A new approach in the study of vertisol morphology *J. Indian Soc. Soil Sci.* **25 (3)** :221-232.

Blokhuis, W.A. (1982). Morphology and gensis of vertisols. Symposia, Paper-II, 12th *International Congress of Soil Science,*New Delhi.

Bourne, W.C. and Whiteside, E.P. (1962). A study of the morphology and pedogenesis of a medial chernozem developed on loess. *Soil Sci. Soc. Am. Proc.* **26** : 484.

Challa, O. and Gaikward, S.T. (1986). Soils in a catena from Dadra and Nagar Haveli, their characterstics and classification. *J. Indian Soc. Soil Sci.* **34** : 543-550.

Challo, O.; Bhaskar, B.P.; Anantpur, S.G. and Gaikward, M.S. (2000). Characterisation and classification of some problematic vertisols in semi arid ecosystem of Maharastra Plateau. *J. Indian Soc. Soil Sci.* **48** (1) 139-145.

Chopra, S.L. and Kanwar, J.S. (1986). *Analytical Agril. Chemistry*, Kalyani Publishers, New Delhi.

Das, N. (1994). P.G. thesis submitted to O.U.A.T. for M.Sc. (Ag) degree.

Dasog, G.S. and Hadimani, A.S. (1980). Genesis and chemical properties of some vertisols. *J. Indian Soc. Soil Sci.* **28 (1)** : 49-56.

Desai, A.D. (1942). The nature and relationship of black cotton soil and red earth of Hyderabad (Deccan). *State Dept. Agril.* Bul. 10.

Deshmukh, S.N. and Bapat, M.V. (1993). Characterisation and classification of soils in relation to different parent rocks and land form. *J. Indian Soc. Soil Sci.* **41**: 326-330.

Dible, W.T.; Truog, E. and Berger, K.C. (1954). *Anal. Chem.* **26** -418.

Diwanker, D.P.S. and Singh , R.N. (1992). Tal land soils of Bihar - I characterisation and classification. *J. Indian Soil. Soc. Sci.* **40**:496 - 504.

Diwankar, D.P.S. and Singh, R.N. (1992). Tal land soils of Bihar - IV; micronutrient in soils, clays and concretion. *J. Indian Soc. Soil, Sci.* **40** : 716- 719.

Diwankar, D.P.S. and Singh, R.N. (1992). Tal land soils of Bihar - II, mineral assemblage. *J. Indian Soc. Soil Sci.* **40** : 544-548.

Diwankar, D.P.S. and Singh, R.N. (1995). Some vertisols and associated soils of Bihar; mineralogy and genesis of concretions and nodules. *Agro Pedology.* **5** : 1-8.

Diwankar, D.P.S. and Singh, R.N. (1995). Micronutrients in soil, clays, and concretion in vertisols of Bihar, *Agropedology.* **5** : 59-62.

Dokuchaive (1879). Soils their origin and their classification as quoted by Robinson (1932).

Follet and Lindsay (1970). *Tech. bull. Colo. agric. Exp. Stn,* 110.

Ghildyal, B.P. and Satyanarayana. T. (1965). *J. Indian Soc. Soil Sci.,* **13** :149.

Gowaiker, A.S. and Barde, N.K. (1964). Soil survey and land capability classification in Vidarbha, Maharastra, *J. Soil and Water Conv.* Jan-June, 32.

Hilgard F. (1893). Soil Nework.

Hirekurubar, B.M.; Doddamani and Satyanarayan (1991) Some physical properties of vertisols derived from different parent material. *J. Indian Soc. Soil Sci.* **39**: 242-245.

Hosking, J.S. (1935). A comparative study of black earth of Australia and the regurs of India. *Trans. Ray. Soc. S. Austr.* **59**: 168.

Jackson , M.N. (1976). *Soil chem. analysis-Advance course*, Dept. Soil. Sci. University of Wisconsin, Madison, U.S.A.

Jenny, H. (1941). *Factors of soil formation*, Mc. Graw Hill series, Book Co. 64

Karale, R.L.; Tamhane, R.V.. and Das,S.C. (1969). *J. Indian Soc. Soil Sci.***17**:227.

Kaswala, R.R. and Despande, S.B. (1983). Physico-chemical characteristics of some coastal and inland soil series of south Gujrat. *J. Indian Soc. Soil Sci.* **31 (2)** : 281-286.

Kaswala, R.R. and Despande, S.B. (1986). Mineralogical characteristics of some coastal and inland soil series of south Gujrat. *J. Indian Soc. Soil Sci.* **34(1)** :160 - 168.

Kausal, G.S.; Tembhare, B.R. and Siha, S.B. (1986). Morphology and Taxonomy of black soils under Bargi Irrigation Project in Madhya Pradesh. *J. Indian Soc. Soil Sci.* **34 (2)** : 329-333.

Kitjah - kosayodam (1986). Chemical and mineralogical properties of vertisols in Lop Buri province (Thailand). Bangkok (Thailand). 237 leaves.

Krishnamurthy. P. and Gobindarajan S.V. (1977). *J. Indian Soc. Soil Sci.,***25**:239.

Leather, F. (1898). As quoted by Raychaudhury (1963) in "Black Soils in India"

Linday, W.L. and Norvell, W.A. (1978). Proc. *Soil Sci. Soc. Am.* **42** :421.

Maji, B.; Bandyopadhya, B.K.; Sarkar, D. and Chatterjee, S. (1998). Morphological and chemical characteristics of soils of Sagar Island of the Sundarbans, West Bengal. *J. Indian Soc. Soil Sci.* **46** : 99-102

Manjaiah, K.M. and Ghosh, S.K. (1995). Clay mineralogy of some soils of Karnataka. *J. Nuclear Agril. and Biology.* **24 (1)** : 41 - 48.

Marbut, C. (1921). *Soil of U.S. Atlas of America, Agril.* Part II, U.S. Govt. Printing office.

Mehta, V.S. and Singh, V. (1988). *J. Indian Soc. Soil Sci.* **36** : 190.

Mermut, A.R.; Dasog, G.S. and Dowuona, G.N. (1996). Soil morphology in vertisol and technologies for their management. *Netherland*, 89-114.

Mitra,G.N.; Sahoo, D and Sahu, G.C. (1980). A laboratory manual of soil and water testing. *Dept. of Soil and Agril. Chemistry,* O.U.A.T., Bhubaneswar.

Mohapatra, P.N. (1966). P.G. Thesis, submitted to O.U.A.T. Bhubaneswar for M.Sc. (Ag.) Degree.

Murthy, R.S.; Bhattacharjee, J.C.; Landey, R.J. and Pofali, R.M. (1982). Distribution, characteristics and classification of vertisols. Symposia Paper-II, *12th International Congress of Soil Science,* New Delhi.

Murthy, I.Y.L.N.; Sastry, T.G. and Datta, S.C. (1997). Distribution of micronutrient cations in vertisols derived from different parent material. *J. Indian Soc. Soil. Sci.* **45(3)** : 577-580.

Olsen, S.R. ; Cole, C.V. ; Watanabe, F.S. and Dean, L.A. (1954). Circ. U.S. Dept. Agril. 939.

Padmaja, G.J.; Sreenivasaraju, A. and Rao. K.V.S. (1993). Status and distribution of sulphur in some pedons of vertisol. *J. Indian Soc. Soil Sci.* **41 (3)** : 560 -561.

Padole, V.R. (1997). Morphology, genesis, clay mineralogy and classification of soils of Central Demonstration farm, Akola. P.K.V. *Research. J.* **21 (1)** : 6 - 12.

Page, A.L.; Miller, R.H. and Keeney, D.R. (1982). *Methods of soil analysis*, Part-2. Am. Soc. Agro. Inc. publisher- Madison, Wisconsin U.S.A.

Panigrahi, S.K. (1995) P.G. Theisis submitted to OUAT for M.Sc. (Ag) thesis .

Paramasivam, P. and Gopalswamy, A. (1994). Distribution of micronutrients in lower Bhavani Project command area soil profiles. *Madras Agril. J.* **81(10)** : 545-547

Paramsivam, P. (1995). Infiltration rate, hydraulic conductivity and moisture retention characteristics of some soils of lower Bhavani Project command area, Tamil Nadu. *Madras Agril. J.* **82 (3)** : 190 -192.

Paranjape, M.V.; Pal, D.K. and Deshpande, S.B. (1997). Genesis of non-vertic deep black soils in Basaltic land form of Maharastra. *J. Indian Soc. Soil Sci.* **45 (1)** : 174-180.

Pharande, A.L. and Sonar, K.R. (1997). Clay mineralology of some vertisols soil series of Maharastra. *J. Indian Soc. Soil Sci.* **45 (2)** : 373-377.

Prasad, A.; Totey, N.G. ; Singh, A.K., Kulkarni. R.; Khatri. P.K.; Bhaumik, A.K.; Chauhan, J.S. and I Dahia, V.K. (1989). Profile development in relation to topography. *J. Indian Soc. Soil Sci.*. **37**: 790 -797.

Prasad. J.; Satyavati. P.L.A.; Srivastava, R. and Nair, K.M.(1995). Characterisation and classification of soils of Nasik district, Maharastra. *Agropedology*. **5** : 25 -28.

Padmaja, G.J.; Sreenivasaraju, A. and Rao. K.V.S. (1993). Status and distribution of sulphur in some pedons of vertisol. *J. Indian Soc. Soil Sci.* **41 (3)** : 560 -561.

Padole, V.R. (1997). Morphology, genesis, clay mineralogy and classification of soils of Central Demonstration farm, Akola. P.K.V. *Research. J.* **21 (1)** : 6 - 12.

Page, A.L.; Miller, R.H. and Keeney, D.R. (1982). *Methods of soil analysis*, Part-2. Am. Soc. Agro. Inc. publisher- Madison, Wisconsin U.S.A.

Panigrahi, S.K. (1995) P.G. Theisis submitted to OUAT for M.Sc. (Ag) thesis .

Paramasivam, P. and Gopalswamy, A. (1994). Distribution of micronutrients in lower Bhavani Project command area soil profiles. *Madras Agril. J.* **81(10)** : 545-547

Paramsivam, P. (1995). Infiltration rate, hydraulic conductivity and moisture retention characteristics of some soils of lower Bhavani Project command area, Tamil Nadu. *Madras Agril. J.* **82 (3)** : 190 -192.

Paranjape, M.V.; Pal, D.K. and Deshpande, S.B. (1997). Genesis of non-vertic deep black soils in Basaltic land form of Maharastra. *J. Indian Soc. Soil Sci.* **45 (1)** : 174-180.

Pharande, A.L. and Sonar, K.R. (1997). Clay mineralology of some vertisols soil series of Maharastra. *J. Indian Soc. Soil Sci.* **45 (2)** : 373-377.

Prasad, A.; Totey, N.G. ; Singh, A.K., Kulkarni. R.; Khatri. P.K.; Bhaumik, A.K.; Chauhan, J.S. and I Dahia, V.K. (1989). Profile development in relation to topography. *J. Indian Soc. Soil Sci..* **37**: 790 -797.

Prasad. J.; Satyavati. P.L.A.; Srivastava, R. and Nair, K.M.(1995). Characterisation and classification of soils of Nasik district, Maharastra. *Agropedology.* **5** : 25 -28.

Prasad. J. and Gajbhiye, K.S. (1999). Vertical distribution of micronutrient cations in some vertisol profiles occuring in different ecoregions. *J. Indian Soc. Soil Sci.* **47 (1)** : 151-153.

Ray Chaudhury, S.P. (1963) : Black Soils of India - A monograph *Nat. Inst. Sci.* India.

Ray Chaudhury, S.P.; Roy, B.B.; Gupta, S.P. and Dewan, M.L. (1963) : *Nat. Inst. Sci. India,* monograph-3.

Robinson. G. (1932). The nature of clay and its significance in weathering cycles. *Nature*, **121** : 903.

Roy, B.B. and Barde, N.K. (1962). Some characteristics of black soils of India. *Soil Sci.* **93** : 142.

Rudramurthy, H.V. ; Dasog, G.S. and Vasuki, K. (1996). Genesis and classification of associated red and black pedons of N. Karnataka *Mysore J. Agril. Sci.* **30 (4)** : 321-330.

Sahu, G.C.; Nanda, S.S.K. and Panda, N. (1982). Genesis and mineralogy of some vertisols in Orissa-I, morphology, genesis and classification. *O.U.A.T. J. Res. Vol. XII(No. 1&2)*: 01-12

Sahu, G.C.; Panda, N. and Nanda, S.S.K. (1990). Genesis and mineralogy of some vertisols of Orissa - II , mineralogy of clay fractions. *Orissa J. Agril. Res.* Vol **3 (3-4) :** 221 - 226.

Sahu, G.C. and Dash, S.S. (1993). Characterisation and classification of salt affected coastal soils of Astaranga, Orissa. *J. Indian Soc. Soil Sci.* **41** : 138 -144.

Sahu, G.C. and Mishra, K.N. (1997). Morphology, characteristics and classification of soils of an irrigated river flood dlain in Eastern Coastal region. *J. Indian Soc. Soil Sci.* **45** : 152 - 156.

Sarkar, D.; Tampi, C.J.; Sehgal, J. and Velayuthan, M. (1998). *Soils of Orissa for optimising landuse.* N.B.S.S. and L.U.P. , Pub. 49., Nagpur.

Satyanarayan, K.V.S.; Dhir, R.P.; Krishnamurthy, G.S.R. and Prem Jolly (1970). *Curr. Sci.* **39** : 211.

Satyavati, P.L.A.; Sharma, J.P. and Srivastava, R. (1994). Contribution of soil organic matter, clay and silt to the cation exchange capacity of Soil. *J. Indian Soc. Soil Sci.* **42** : 14 -17.

Saxena, S.C. and Singh, K.S. (1982). Pedochemical characterisation of soils of Rajasthan. *J. Indian Soc. Soil Sci.* **30** : 515 -522.

Shanwal; Jain, A.V., and Karwasra, A.K. (1998). Characterisation and classification of soils of farms of Haryana Agricultural University, Hissar, Haryana. *Haryana Agril. University J. Res.* **18** : 177 -186.

Sharma, R.R. and Bhargava, G.P. (1973). Classification of some black soils of Tungabhadra catchmeent area in Mysore state. *Indian J. Agril. Research* Vol. **7** : 23-32.

Sharma, O.P. and Dubey, D.D. (1988). Potassium status of vertisols and associated soils in a toposequence. *J. Indian Soc. Soil Sci.* **36 (2)**:363-366.

Sharma and Lal (1992). Status of D.T.P.A. Zn in vertisols *J. Indian Soc. Soil Sci.* **40** : 393-394.

Sharma, S.P.; Sharma, P.D. ; Singh, S.P. and Minhas, R.S. (1993). Characterisation of soan river valley soils in Lower siwaliks of Himachal Pradesh, I. Hill soils. *J. Indian Soc. Soil Sci.* **41** : 714-719.

Shyampura, R.L. ; Giri, J.D.; Das, K. and Singh, S.K. (1994). Soil-physiogrphic relationship on a transect in Southern Rajasthan. *J. Indian Soc. Soil Sci.* **42**: 622-625.

Simonson, Roy, W. (1954). *J. Soil Sci.,* **5 :** 275.

Singh, N.T. ; Mongia, A.D. and Ganeswar murthy, A.N. (1988) Soils of Andaman Nicober Island. CARI Bulletin.

Singh, M. and Sekhon, G.S. (1991). D.T.P.A. extractable micro nutrient cations in 20 soil series of India. *J. Indian Soc.Soil Sci.* **39** : 129 -133.

Singh, S.K. ; Das, K.J.; shyamapura, R.L. ; Giri, J.D. and Singh, R.S. (1995). Genesis and Taxonomy of black soils from basalt and basaltic alluvium in Rajasthan. *J. Indian Soc. Soil Sci.* **43 (3)** : 430 - 436.

Soil Survey Staff (1975). *Soil Taxonomy, Agril. Hand b.* U.S. Dep. Agric. 436.

Soil Survey Staff . (1995). *Soil Survey Manual* USDA Hand b-18 (Indian reprint) Scientific Publisher, Jodhpur -1).

Soil Survey Staff (1998). *Keys to soil Toxonomy*, Eight Edn. 1998, U.S. Dep. Agric. Nat. Res. Cons. Service.

Subbaiah, G.V. and Manickam J.S. (1992). Genesis and morphology of vertisols developed on different parent material.*J. Indian Soil Sci.* **40(1)**:150-155.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the determination of available nitrogen in *SoilCurr. Sci.* **25** : 259-260.

Surekha, K; Subbarao, I.V.R. and Santaram, M.K. (1997) Characterisation of some vertisols of Andhra Pradesh. *J. Indian Soc. Soil Sci.* **45(2)**:338-343.

Tamhane, R.V. (1950). Regur soils of India. *Trans. 4th inst. conf.Soil Sci.***3** : 131.

Tiwari, J.R.; Jha, P.P. and Mishra, B.B. (1989). Characteristics and classification of red, black and yellow soils of Rajmahal trap of Bihar. *J. Indian Soc. Soil Sci.* **37 (3)** : 518 -523.

Tiwari, J.R. and Mishra B.B. (1990). Distribution of micronutrients in Tal land soils (**Udic chromustert**) of Bihar. *J. Indian Soc. Soil Sci.* **38** : 319-321.

Tiwari, A.K. and Bansal, K.N. (1992). Vertical distribution of forms of potassium in some soil series of N. Madhya Pradesh. *J. Potassium Research.* **8(3)** : 223 - 230.

Tiwari, J.R. and Mishra, B.B. (1993). Clay mineralogy of black soils of Rajmahal trap of Bihar. *J. Indian Soc. Soil Sci.* **41 (3)** : 535 -540.

Vander merwe,C.R. (1940). Conf. on tropical and subtropical Soil *Tech. Com.* No 40 England (Abstract soil and fertilizers)

Venugopal, K.R.; Pal, D.K. and Despande, S.B. (1989). Micromorphology and mineralogy of shrink-swell soils formed on Basaltic Gneiss. *J. Indian Soc. Soil Sci.* **38 (1)** : 108 -112.

Viswanatha, J. and Doddamani (1991). Distribution of phosphorus fraction in some vertisols. *J. Indian Soc. Soil Sci.* **39** : 441-445.

Walia, C.S. and Rao, Y.S. (1997). Fine sand and silt mineralogy of some inceptisols and vertisols of Trans Yamuna Plain in relation to land forms. *J. Indian Soc. Soil Sci.* **45 (4)**: 812-815.

William, D.; Cook, T; Lynn, W and Eswaran, H. (1996). *Soil Survey Horizon.* **37(4)** :123 - 131.

Yadav, B.R. ; Gupta, R.N. and Singh, B.D.(1977) Catenary relationship existing among the soils of the lower Vindhyan Plateau in Uttar Pradesh. *J. Indian Soc. Soil Sci.* **25** : 253 - 259.

Tiwari, J.R. and Mishra B.B. (1990). Distribution of micronutrients in Tal land soils (**Udic chromustert**) of Bihar. *J. Indian Soc. Soil Sci.* **38** : 319-321.

Tiwari, A.K. and Bansal, K.N. (1992). Vertical distribution of forms of potassium in some soil series of N. Madhya Pradesh. *J. Potassium Research.* **8(3)** : 223 - 230.

Tiwari, J.R. and Mishra, B.B. (1993). Clay mineralogy of black soils of Rajmahal trap of Bihar. *J. Indian Soc. Soil Sci.* **41 (3)** : 535 -540.

Vander merwe,C.R. (1940). Conf. on tropical and subtropical Soil *Tech. Com.* No 40 England (Abstract soil and fertilizers)

Venugopal, K.R.; Pal, D.K. and Despande, S.B. (1989). Micromorphology and mineralogy of shrink-swell soils formed on Basaltic Gneiss. *J. Indian Soc. Soil Sci.* **38 (1)** : 108 -112.

Viswanatha, J. and Doddamani (1991). Distribution of phosphorus fraction in some vertisols. *J. Indian Soc. Soil Sci.* **39** : 441-445.

Walia, C.S. and Rao, Y.S. (1997). Fine sand and silt mineralogy of some inceptisols and vertisols of Trans Yamuna Plain in relation to land forms. *J. Indian Soc. Soil Sci.* **45 (4)**: 812-815.

William, D.; Cook, T; Lynn, W and Eswaran, H. (1996). *Soil Survey Horizon.* **37(4)** :123 - 131.

Yadav, B.R. ; Gupta, R.N. and Singh, B.D.(1977) Catenary relationship existing among the soils of the lower Vindhyan Plateau in Uttar Pradesh. *J. Indian Soc. Soil Sci.* **25** : 253 - 259.

Tiwari, J.R. and Mishra B.B. (1990). Distribution of micronutrients in Tal land soils (**Udic chromustert**) of Bihar. *J. Indian Soc. Soil Sci.* **38** : 319-321.

Tiwari, A.K. and Bansal, K.N. (1992). Vertical distribution of forms of potassium in some soil series of N. Madhya Pradesh. *J. Potassium Research.* **8(3)** : 223 - 230.

Tiwari, J.R. and Mishra, B.B. (1993). Clay mineralogy of black soils of Rajmahal trap of Bihar. *J. Indian Soc. Soil Sci.* **41 (3)** : 535 -540.

Vander merwe,C.R. (1940). Conf. on tropical and subtropical Soil *Tech. Com.* No 40 England (Abstract soil and fertilizers)

Venugopal, K.R.; Pal, D.K. and Despande, S.B. (1989). Micromorphology and mineralogy of shrink-swell soils formed on Basaltic Gneiss. *J. Indian Soc. Soil Sci.* **38 (1)** : 108 -112.

Viswanatha, J. and Doddamani (1991). Distribution of phosphorus fraction in some vertisols. *J. Indian Soc. Soil Sci.* **39** : 441-445.

Walia, C.S. and Rao, Y.S. (1997). Fine sand and silt mineralogy of some inceptisols and vertisols of Trans Yamuna Plain in relation to land forms. *J. Indian Soc. Soil Sci.* **45 (4)**: 812-815.

William, D.; Cook, T; Lynn, W and Eswaran, H. (1996). *Soil Survey Horizon.* **37(4)** :123 - 131.

Yadav, B.R. ; Gupta, R.N. and Singh, B.D.(1977) Catenary relationship existing among the soils of the lower Vindhyan Plateau in Uttar Pradesh. *J. Indian Soc. Soil Sci.* **25** : 253 - 259.