

MORPHOLOGY AND TAXONOMY OF SOILS IN RAMACHANDRAPURAM MANDAL OF CHITTOOR DISTRICT IN ANDHRA PRADESH

By

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CERTIFICATE

Mr.A.P.VARA PRASAD RAO has satisfactorily prosecuted the course of research and that the thesis entitled “**MORPHOLOGY AND TAXONOMY OF SOILS IN RAMACHANDRAPURAM MANDAL OF CHITTOOR DISTRICT IN ANDHRA PRADESH**” submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part thereof has not been previously submitted by him for a degree of any University.

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DECLARATION

*I, **Mr.A.P.VARA PRASAD RAO** hereby declare that the thesis entitled “**MORPHOLOGY AND TAXONOMY OF SOILS IN RAMACHANDRAPURAM MANDAL OF CHITTOOR DISTRICT IN ANDHRA PRADESH**” submitted to Acharya N.G. Ranga Agricultural University for the degree of **Master of Science in Agriculture** majoring in **Soil Science and Agricultural Chemistry** is the result of original research work done by me. I also declare that the materials contained in this thesis has not been published earlier.*

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CERTIFICATE

This is to certify that the thesis entitled “**MORPHOLOGY AND TAXONOMY OF SOILS IN RAMACHANDRAPURAM MANDAL OF CHITTOOR DISTRICT IN ANDHRA PRADESH**” submitted in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE** of the Acharya N.G.Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr.A.P.VARA PRASAD RAO** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part has been fully acknowledged. All the assistance and help received during the course of investigations have been duly acknowledged by the author of the thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	percentage
>	:	greater than
<	:	lesser than
nm	:	nano meter
°C	:	Degree Celsius
CEC	:	Cation Exchange Capacity
cmol(p ⁺)kg ⁻¹	:	centimole per kilogram
m	:	meter
cm	:	centimeter
mm	:	millimeter
dSm ⁻¹	:	deci Seimen per meter
EC	:	Electrical Conductivity
<i>i.e.</i>	:	that is
<i>viz.,</i>	:	namely
<i>et al.</i>	:	and others
MAAT	:	Mean Annual Air Temperature
MAST	:	Mean Annual Soil Temperature
MSST	:	Mean Summer Soil Temperature
MWST	:	Mean Winter Soil Temperature
g kg ⁻¹	:	gram per kilogram
mg kg ⁻¹	:	milligram per kilogram
Mg m ⁻³	:	Mega gram per cubic meter
mha	:	million hectare
NBSS & LUP	:	National Bureau of soil Survey and Land Use Planning
USDA	:	United States Department of Agriculture
Fig.	:	Figure
<i>etc.</i>	:	etcetera

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ABSTRACT

The present investigation was carried out to study the morphology and taxonomy of soils in Ramachandrapuram mandal of Chittoor district in Andhra Pradesh. For this, seven representative pedons were selected in seven different locations of the study area covering all types of soils. All the seven pedons were described for their morphological features in the field and horizon-wise samples were collected and analysed in the laboratory for physical, physico-chemical and chemical properties.

Besides, eighty surface soil samples were also collected from different revenue villages of the mandal and processed for laboratory analysis of pH, EC, organic carbon, available macronutrients (N, P, K and S) and micronutrients (Cu, Zn, Fe and Mn) to know the fertility status of the mandal.

The study area was characterised by semi-arid monsoonic climate with distinct summer, winter and rainy seasons. The pedons selected were mostly confined to plain, very gently and gently sloping topography. Pedon 2 was developed from alluvium whereas the remaining pedons originated from granite-gneiss parent material.

The morphological features revealed the presence of AC (Pedons 2, 5, 6 and 7), AB (Pedons 1 and 3) and AEB profiles (Pedon 4). The soils were characterized by moderately deep to very deep, light yellowish brown to dark red colour, sandy to clay loam texture and crumb, sub-angular blocky, angular blocky and single grain structure. Vertic properties such as cracks and slickensides were noticed in pedon 1 only.

The clay content increased with depth in pedon 1 whereas pedons 5 and 7 showed a decreasing trend. Pedon 2 exhibited an irregular decreasing trend and pedons 3, 4 and 6 have shown no specific trend with depth. Physical constants like water holding capacity, loss on ignition and volume expansion followed the trend of clay content. All the pedons recorded an increasing trend of bulk density with depth.

The pedons were slightly acidic to moderately alkaline in reaction, non-saline and low to medium in organic carbon content. All these pedons registered less per cent of CaCO_3 . CEC values were low to medium and the exchange complex was dominated by Ca^{2+} followed by Mg^{2+} , Na^+ and K^+ . Chemical composition of the soils revealed that all the pedons had high silica content indicating siliceous nature.

Regarding the nutrient status, the surface soil samples were low in available nitrogen, low to medium in available phosphorus, medium to high in available potassium and deficient in available sulphur. However, the available zinc and iron were deficient while the available copper and manganese were sufficient in these soils. Pedons 1, 2 and 5 showed the dominance of smectitic clay mineralogy whereas pedons 4 and 6 exhibited dominance of kaolinitic clay mineralogy. However, pedons 3 and 7 showed the dominance of feldspars and illite, respectively.

Based on morphological, physical, physico-chemical, chemical, mineralogical and climatic data, the soils of Ramachandrapuram mandal were classified as:

Pedon 1:	Fine-loamy, smectitic, iso-hyperthermic, Vertic Haplustepts
Pedon 2:	Fine-loamy, siliceous, iso-hyperthermic, Typic Ustipsamments
Pedon 3:	Fine-loamy, mixed, iso-hyperthermic, Typic Haplustepts
Pedon 4:	Fine-loamy, kaolinitic, iso-hyperthermic, Typic Haplustalfs
Pedon 5:	Fine-loamy, siliceous, iso-hyperthermic, Typic Ustifluvents
Pedon 6:	Fine-loamy, siliceous, iso-hyperthermic, Typic Ustorthents
Pedon 7:	Fine-loamy, siliceous, iso-hyperthermic, Typic Ustorthents

Based on soil properties, the soils of Ramachandrapuram mandal have been classified into land capability sub-classes *viz.*, IIs (Pedons 1 and 3), IIIs (Pedon 2), IIIs (Pedons 4 and 5) and IVes (Pedons 6 and 7).

CHAPTER – I

INTRODUCTION

Soil is an essential natural resource for the sustained agricultural development. Soil provides anchorage and nourishment to vegetation. Soil provides a habitat for biological life and a base for the development of civilizations. Soil is dynamic, always changing as a result of the forces of nature and particularly by human influences.

India has a total geographical area of about 328 m ha with different types of soils, of which red and associated soils occupy an area of 70 m ha. While Andhra Pradesh has a land area of 274.4 lakh ha and it accounts for 8.4 per cent of the country's area. The state is endowed with a wide variety of soils wherein red and associated soils cover an area of about 178.36 lakh ha and occupy 65 per cent of the total area of the state. Red soils are found in all the districts of the state, majority of them being present in Telangana and Rayalaseema regions (Subba Rao and Rao, 1998).

The study of soils today has an increased importance due to rapidly declining land area for agriculture, declining soil fertility and increasing soil degradation through unbridled population increase, urbanization, wrong land use policies and irrational and imbalance use of inputs (Kanwar, 2004). All the above factors necessitate significant shift in emphasis of soil science research away from maximum crop production to the sustainability of crop production systems through maintaining the soil health without undergoing deterioration.

To achieve sustainable yields in crops besides maintaining soil health, needs a thorough and proper understanding of morphological, physical, physico-chemical and chemical characteristics of the soils. Further, to establish environmentally sound, socially desirable and economically feasible land use the site specific information of soils is highly essential which can be acquired through soil survey involving systematic study of morphology and taxonomy of soils.

Soil classification helps in grouping and mapping of soils with similar properties and suggesting suitable management practices for increasing the productivity of the soils. The soil classification (Taxonomy) is also important to identify the most efficient use of soils by estimating their productivity potential and extrapolating the knowledge thus gained at one location to another similar soil for technology transfer.

Detailed information regarding morphological, physical and chemical properties of soils in Ramachandrapuram mandal from systematic studies using standard procedures is not available so far. Therefore, systematic study on morphology and taxonomy of the soils of this mandal is most essential for increasing the crop production and also for suggesting optimum land use plan.

Keeping the above facts in view, the present investigation is undertaken with the following objectives:

- To study the morphological features of soil profiles of Ramachandrapuram mandal.

- To characterise the soils of each horizon for distinct physical, physico-chemical and chemical properties.
- To classify the soils as per USDA Soil Taxonomy upto family level.
- To classify the soils of Ramachandrapuram mandal into different capability classes (USDA) for optimum land use planning.

CHAPTER - II

REVIEW OF LITERATURE

Soil is an independent, dynamic body of nature that acquires properties in accordance with the forces that act upon it. The capacity of a soil to produce is limited and the limits of production are set by its intrinsic characteristics, agroecological settings, use and management. However, no developmental plan can be successful unless it is based on reliable knowledge on the extent of different kinds of soils in relation to climate, vegetation and potential crop production and how best this finite natural resource is managed for the benefit of the existing and future generations. In India, the research work done on red and associated soils is not exhaustive and there is need for detailed investigation. Hence, the present investigation was planned and carried out. However, the available literature on relevant aspects is reviewed and presented under appropriate sub-heads hereunder.

2.1 NOMENCLATURE

A major feature of the classification system is the nomenclature used to identify different soil classes. The names of the classification units are combinations of symbols, most of which are derived from Latin or Greek and have root words in several modern languages. Since, each part of soil name conveys a concept of soil character or genesis, the name automatically describes the general kind of soil being classified. This was the opinion of Brady (1990) about the nomenclature of soils.

The red and associated soils occupy one-fifth of the total geographical area in our country and designated by different names in different parts of the country. In Andhra Pradesh, red sandy loam soils with permeable murrum developed on the side slopes and foot hills are locally called *chalka* soils while the coarse textured loamy sand and sandy soils are known as *dubba* soils. Red and dark red soils found in Karnataka were commonly called as *kisumattaru*. In Jhansi district of Uttar Pradesh two types of red soils are met with *parwa* and *rakar*. The brownish gray soil varying from loam to sandy or clay loam is called *parwa* and the red soils not suitable for cultivation are named *rakar* (Rayachaudhuri and Govinda Rajan, 1971).

2.2 PEDOGENESIS

Dokuchaev (1883) laid foundation for soil genesis and expressed that the soil was an independent natural evolutionary body formed under the influence of five soil forming factors *viz.*, parent material, climate, organisms, topography and time. Among the soil forming factors, he considered vegetation as the most important one. Jenny (1941) reported that the soil forming factors were independent variables, each of them can change and vary from place to place without the influence of other. Variations in rainfall and topography resulted in differential leaching which in turn led to the formation of different soils *viz.*, black, brown and laterites (Karale *et al.*, 1969).

The soils in tropical areas were characterised by reddish colour due to the desilication, leaching, illuviation, desiccation and lateral movement of soil solute along the slopes (Bhattacharyya *et al.*, 1993). Patil and Dasog (1997) stated that the eluviation, illuviation and transformation were the main pedogenic processes for the formation of iron oxides. Sidhu *et al.* (1998) noticed that the activity of soil forming process was more perceptible in the

direction of active to old flood plain and from hill top to lower piedmont plain. Accumulation of higher Al_2O_3 / Fe_2O_3 at the surface than in the sub-surface provided confirmatory evidence of clay translocation in the soils (Singh *et al.*, 1998). Dipak Dutta *et al.* (1999) pointed out that the soil development in a terrain of Andhra Pradesh was related to weathering ratios, lithology, topography and hydrology.

The major factors responsible for the development of Entisols in the Lakshadweep islands were the action of physical forces like wind and waves, which disintegrated the hard coral reef and subsequent biological activity (Krishnan *et al.*, 2004). Illuviation process occurred during soil development was responsible for higher clay content in the sub-surface horizons as compared to surface horizons (Sharma *et al.*, 2004).

2.3 FACTORS OF SOIL FORMATION

The influence of different soil forming factors on soil development was presented below.

2.3.1 Parent material

The nature of the parent material profoundly influences soil characteristics like texture *etc.* The chemical and mineralogical composition of parent material also influences both chemical weathering and natural vegetation. Parent material also influences the quantity and type of clay minerals present in the soil profile.

Indian red soils were developed from acid granite and allied Cuddapah and Vindhyan sandstones with colour grading from brown, chocolate, yellow to gray (Wadia, 1960). Coarse textured illitic and kaolinitic soils were developed from granite-gneiss type of rocks rich in quartz and orthoclase feldspar (Bhargava *et al.*, 1973). According to Digar and Barde (1982) the red soils were derived mostly from granites, gneisses and schist mainly of Archaean period. Other rocks include sandstone, mica-schist, acid trap, quartzite shale, charnockite and diorite.

Sahu *et al.* (1983) reported that the red soils of Eastern ghat were developed on charnockite and khondalite rocks. The red soils of Rajmahal trap in Bihar were formed from granite-gneiss type of

rock (Tiwary *et al.*, 1987). Red and yellow soils were developed from granite in south west China (Felix *et al.*, 1989). Some of the red soils in Rajmahal trap of Bihar were also formed from basalt (Tiwary and Mishra, 1992). The red soils of Raisen district of Madhya Pradesh were developed on sandstone, basalt and alluvium (Deshmukh and Bapat, 1993). Walia and Rao (1996) stated that the red soils of Bundelkhand region of Uttar Pradesh were originated from sandstone, shale, granite and colluvium.

Soils of North-West India have mostly developed on alluvium deposited by the rivers of Indus system (Dhaliwal *et al.*, 1996). The soils of Punjab in North-West India were young and had developed on alluvial parent material (Sharma *et al.*, 1997). Sidhu *et al.* (1998) pointed out that the soils developed on sandstones were coarser in texture whereas soils developed on alluvial terraces were fine textured. Soils of Chandrapur in Maharashtra were derived from shale and sandstone (Thakre *et al.*, 1998). Red soils, occupying about 65 per cent of land area in Andhra Pradesh state were predominant soils formed on granites, gneisses and Dharwars (schist, mica-schist and greenstones) and sandstones (Subba Rao and Rao, 1998).

Dipak Dutta *et al.* (1999) stated that the Alfisols of Andhra Pradesh had developed from the granite-gneiss. Rudramurthy and Dasog (2001) reported that the red and associated black soils in Karnataka were formed from basalt, granite - gneiss and chlorite - schist. The red soils in Krishna district of Andhra Pradesh were developed from granite-gneiss parent material mixed with sandstone and quartzite (Ramprakash and Seshagiri Rao, 2002).

The banana growing soils of Wardha district in Maharashtra were deep (>100 cm) and developed on recent alluvium (Kadao *et al.*, 2003). The *sal* (*Shorea robusta*) supporting soils in Dindori district of Madhya Pradesh were originated from laterised basalt (Patil and Jagdish Prasad, 2004). The Inceptisols and Vertisols in Telangana region of Andhra Pradesh were originated from igneous rocks such as pink and grey granites and basalt and metamorphic rocks *viz.*, granite-gneiss and hornblende schists (Satyavathi and Suryanarayan Reddy, 2004). Entisols, Inceptisols and Alfisols were developed from granite gneiss and quartzite parent materials in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh (Thangasamy *et al.*, 2005).

2.3.2 Climate

Climate is the active factor and important among the four factors acting on parent material because it determines the nature and intensity of the weathering that occurs over large geographic areas. The principal climatic variables influencing soil formation were effective precipitation and temperature, both of which affect the rates of chemical, physical and biological processes.

The studies on the effect of climate and parent material on the nature and properties of hill soils of Himachal Pradesh revealed that the climate and parent material appeared to be decisive in characterising the soils through their effects on intensity of the soil development (Verma *et al.*, 1987). The red, black and yellow soils in Rajmahal trap of Bihar was formed in tropical monsoon type of climate with an average annual rainfall of 1256 mm (Tiwary *et al.*, 1989). The red and associated soils in Kavali Command area of Andhra Pradesh were developed from semi-arid monsoonic climate with an annual rainfall of 887 mm (Prasuna Rani *et al.*, 1991).

The red soils in Kandukur division of Prakasam district, Andhra Pradesh were confined to the semi-arid monsoonic climate. (Jagannadham *et al.*, 1995). Jagdish Prasad *et al.* (1995) observed the development of Typic Rhodustalfs under hot humid climate, Typic Ustropepts under sub-humid zone and Chromic Haplusterts in semi-arid climate of Maharashtra.

The soils of Kuanria irrigation project of Orissa were formed in sub-tropical sub-humid monsoonic climate with an annual rainfall of 1281 mm and the mean annual temperature being more than 27.2°C (Nanda *et al.*, 1997). The Alfisols of Andhra Pradesh were formed in hot semi-arid climatic conditions with mean annual temperature of 27.6°C and the rainfall of 850 mm (Dipak Dutta *et al.*, 1999).

Dutta *et al.* (2001) stated that the deep weathering required a tropical climate with a rainfall of more than 1600 mm per annum. The soils of Etawah district of Uttar Pradesh had developed in semi-arid sub-tropical climate with an annual precipitation of 775 mm and the mean maximum and minimum temperatures were being 42°C and 26°C in summer and 23°C and

8°C in winter, respectively (Verma *et al.*, 2001). Ramprakash and Seshagiri Rao (2002) stated that the red and black soils of Krishna district in Andhra Pradesh were developed from semi-arid monsoonic climate with a mean annual rainfall of 1090 mm. The red and black soils in Dindori district of Madhya Pradesh were formed in moist sub-humid climate with an annual rainfall of 1460 mm (Patil and Jagdish Prasad, 2004). Climatically northern Telengana Zone falls under semi-arid (moist) tropics with an annual rainfall of around 1000 mm whereas southern Telengana zone falls under semi-arid (dry) tropics with an annual rainfall of around 740 mm. Further, the moisture and temperature regimes in southern and northern zones was ustic and iso-hyperthermic (Satyavathi and Suryanarayan Reddy, 2004).

The Entisols, Inceptisols and Alfisols were developed under semi-arid monsoonic climate with an annual rainfall of 1215 mm and mean annual air temperature of 31.5°C. Further, the soils were found to have iso-hyperthermic soil temperature regime and ustic soil moisture regime (Thangasamy *et al.*, 2005).

2.3.3 Time

Time is an important factor in the course of soil development which governs indirectly the activities and interactions of different factors of soil formation.

The studies on the sand mineralogy of alluvium derived soils of southern bank of Bramhaputra river in Assam revealed that the lowest weathering was observed in soils developed on the recent alluvium (Chakravarthy *et al.*, 1979). Soil development increased with the logarithm or power of soil age (Natasa *et al.*, 1997). According to Lekha *et al.* (1998) the soils developed over granite-gneiss were comparatively younger with higher nutrient reserves followed by soils developed over granite, charnockites and laterites.

Nayak *et al.* (1999) observed that the colour became redder with increasing age and its quantitative index (Hurst index) showed the highest value in soils of Archaean age, intermediate in pleistocene age and the lowest in soils of Holocene age. Tamgadge *et al.* (1999) reported that the clay content was less than 35 per cent in young / immature soils while it was medium (35-55%) in mature soil and high (> 55%) in old soils. The soils of active flood

plain in Etawah district of Uttar Pradesh were formed on repeated fresh sediments and hence could not get sufficient time for development (Verma *et al.*, 2001).

2.3.4 Topography

Topography relates to the configuration of the land surface and is described in terms of differences in elevation, slope and landscape position. The specificity of many properties of a given soil material is the result of its unique position with respect to the surface and the substratum and its development cannot be well understood except in relation to its position as it occurs in nature.

Arun Prasad *et al.* (1989) studied the soils in relation to topography and noticed that the soils on hill top, mid slope and foot hill upland were reddish brown to dark reddish brown whereas soils occurring on slopes and depressions were dark to very dark grayish brown. Tiwary *et al.* (1989) reported that the red soils were mostly located on the uplands with steep slopes and moderate to well drained conditions as compared to the black soils which are olive gray to black in colour and situated mainly at low lands having impeded drainage, slow permeability and gentle slope.

Seshagiri Rao *et al.* (1992) observed that the enrichment of iron oxides with depth was due to intense weathering and subsequent loss of bases due to their position at higher topography. The pedons of upper slopes were fairly developed (Haplustalfs) as compared to pedons situated in the lower side slope (Ustochrepts) and valleys (Haplaquepts) in Ajoy catchment of West Bengal (Kudrat *et al.*, 1995). Mishra and Ghosh (1995) stated that the soils developed from steep slope gradient were subjected to intense weathering while the soils developed on gentle slope gradient showed mild weathering.

The soils at higher topography were more weathered than the soils at lower topography (Sharma *et al.*, 1996). The soils in Bundelkhand region of Uttar Pradesh showed wide textural variations caused by physiography, parent material, *in situ* weathering and translocation of clay (Walia and Rao, 1996). Dipak Dutta *et al.* (1999) reported that the soils on undulating uplands showed a considerable loss of clay from the surface and sub-surface than the soils developed on gently sloping uplands.

Soils of different landscape positions in Etawah district of Uttar Pradesh showed different stages of pedogenic development and established a good soil - physiography relationship in that area (Verma *et al.*, 2001). Red soils were present on the gently sloping (3-4%) upper pediplains whereas the black soils were distributed in lower pediplains with very gently sloping (1-3%) terrain in Krishna district of Andhra Pradesh (Ramprakash and Seshagiri Rao, 2002).

The Inceptisols (Dystric Eutrudepts) located in lowlands of Chandauli district of Uttar Pradesh had more clay content than the Entisols (Typic Ustifluvents) developed on the uplands (Singh and Agrawal, 2003). The Vertisols in South coastal Andhra Pradesh were very deep, clayey, moderately well drained and formed on nearly flat to very gently sloping uplands with a slope gradient upto 3 per cent while the Inceptisols were very deep, sandy loam to sandy clay loam, moderately well drained and formed on very gently to gently sloping uplands with a slope of 0-1 per cent (Seshagiri Rao *et al.*, 2004).

2.3.5 Vegetation

Natural vegetation influences the type of soil eventually formed from a given parent material. Vegetation cover by higher plants influences the soil in a number of ways, principally through the addition of organic matter, action of roots in binding soil particles and amelioration of climatic conditions at the soil surface. Further, the diversification in vegetation serves as a good sign of indication for the identification of soil properties.

According to Gaikawad *et al.* (1974) the natural vegetation in associated red and black soils in a toposequence around Nagpur area was palas (*Butia frondosa*), ber (*Ziziphus jujuba*), sal (*Beswellia seratta*), yen (*Terminia tomentosa*) and few shrubs. Arun Prasad *et al.* (1989) observed that the poor vegetative cover promoted high runoff and more erosion when the landscape was undulating resulting in shallow and immature soils.

Prasuna Rani *et al.* (1991) reported that the natural vegetation of red and associated soils of Kavali command area was grasses and xerophytic plants. Dominant vegetation of Devergaon soils of Maharashtra was bushy vegetation with *Acacia* sp. as it

was major component and tall grasses (Jagdish Prasad *et al.*, 1995). The weakly developed structure in the surface horizons of flood - plain soils could be attributed to addition of organic matter to soil surface either through natural vegetation and / or as a result of crop production (Dhaliwal *et al.*, 1996). The pH in the surface soils of Markundi and Tikria in Bundelkhand region was higher than the lower horizons suggesting accumulation of bases on surface through vegetation (Walia and Rao, 1996).

The soils (Inceptisols) of north eastern region had abundant species of flora varying from open shrubs, grasslands to alpine with mixed sub-tropical deciduous and evergreen forest cover (Sen *et al.*, 1997). Jawahar *et al.* (1999) observed that the natural vegetation mainly comprising of *Borassus flabellifer*, *Acacia* sp., *Dodonea viscosa* along with cultivated cashew trees in Theri soils of Tamil Nadu.

The Entisols of Meghalaya plateau was dominated by pine (*Pinus insularis*) with oak, rhododendron, mangolia and other temperate forest trees whereas the Inceptisols were covered with grasses (Bhaskar *et al.*, 2004). The dominant natural vegetation in

the sand dunes and beach sands was short and tall grasses whereas *Prosopis juliflora*, babul, palmyra etc., were dominant in transitional alluvium and inland plains of southern coastal agro-eco sub-region soils of Andhra Pradesh (Seshagiri Rao *et al.*, 2004). The natural vegetation in red and associated soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh includes grasses, *Prosopis juliflora*, *Parthenium* species, *Tridax* species, mango and neem etc. (Thangasamy *et al.*, 2005).

2.4 MORPHOLOGICAL FEATURES

The morphological characteristics are the most imperative key features for classifying soil into defined categories. The morphology of red and associated soils was studied and the pertaining information was well documented. Some of the important contributions are reviewed here under.

2.4.1 Horizon and horizon sequence

The Typic Ustifluvents in parts of Andhra Pradesh showed Ap, C1, C2, C3 and C4 horizon sequence whereas Typic Ustipsamments exhibited Ap, C1, C2 and C3 horizon sequence (Ramakrishna Prasad, 1994). Sidhu *et al.* (1994) observed Ap, C1,

C2, C3 and C4 horizon sequence in Typic Ustorthents while Typic Ustipsamments showed Ap, C1, C2, C3 and C4 horizon sequence.

According to Walia and Rao (1996) the Alfisols in Bundelkhand region of Uttar Pradesh exhibited Ap, Bt1, Bt2 and BC horizon sequence. Dipak Dutta *et al.* (1999) stated that some Alfisols of Andhra Pradesh showed A, Bw, Bt and Cr horizon sequence in Typic Haplustalfs while Typic Rhodustalfs exhibited A, Bw, Bt1, Bt2 and Cr horizon sequence. Sidhu *et al.* (1999) noticed that the Ustifluvents in Jammu region produced A1, C1, C2, C3, C4 and C5 horizon sequence. The Haplustepts in Guntur district of Andhra Pradesh showed Ap, Bw1, Bw2, Bw3, BC and C horizon sequence (Madhuvani, 1999).

Rudramurthy and Dasog (2001) reported that the associated red and black soils in North Karnataka produced Ap, Bw1, Bw2, BC and C horizon sequence in Typic Haplustepts while the Typic Haplustalfs exhibited Ap, Bt1, Bt2, Bt3, BC and C horizon sequence. Verma *et al.* (2001) studied the soil variability across different landscapes in Etawah district of Uttar Pradesh and the study revealed that the Entisols (Ustorthents) showed a horizon

sequence of A11, A12, A13, A14, A15, C1 and C2 while the Inceptisols (Haplustepts) exhibited Ap, Bw1, Bw2, Bw3, Bw4 and Bw5. The Alfisols and Inceptisols of upper Maul khad catchment in Himachal Pradesh were characterized by the presence of eluvial (Ap and AB) and illuvial (BA, Bw, Bt and Bc) horizons of varying thickness (Sharma and Anil kumar, 2003).

2.4.2 Boundary between the horizons

According to NBSS & LUP (1994) the boundary of the soils in Chabalpur series (Entisols) of West Bengal was diffuse smooth, abrupt smooth and clear smooth. Dhaliwal *et al.* (1996) stated that the abrupt/ clear boundaries indicative of marked stratification due to the deposition of different sediments and lack of post depositional inter horizon translocation of chemically mobile constituents and fine particles within a profile.

The boundary of Inceptisols developed on Madhupur clay in Bangladesh was gradual wavy, diffuse wavy, clear wavy, abrupt wavy and abrupt smooth (Elahi *et al.*, 1996). The Inceptisols of North-West India exhibited clear smooth, gradual smooth, diffuse smooth, abrupt smooth and clear / gradual smooth boundary

(Sharma *et al.*, 1997). Lekha *et al.* (1998) noticed that the boundary of the Chunda soils of Kerala developed from hard lateritic pan produced clear smooth and gradual smooth boundary while the soils developed on weathered laterite exhibited gradual smooth, clear smooth and abrupt smooth boundary.

Verma *et al.* (2001) studied the soils of Etawah district of Uttar Pradesh and observed clear smooth and gradual smooth boundary between the horizons. The horizon boundaries in Entisols, Inceptisols and Alfisols of Neogal watershed in North-West Himalayas was clear to diffuse in distinctness and smooth in topography (Sharma *et al.*, 2004).

2.4.3 Soil colour

Soil colour is one of the important basic properties which helps to identify the kinds of soils and recognize the successions of soil horizons / layers in soil profiles. The soil colour of an area, often relates to specific chemical, physical and biological properties of the soils in that area.

The soils developed on granite-gneiss were yellowish red (5 YR 4/6) to strong brown (7.5 YR 7/6) in colour whereas the alluvial soils developed on Mahananda alluvium were pale yellow (2.5 Y 7/4) to olive (5 Y 5/3) in colour (Singh *et al.*, 1993).

The Entisols of different soil moisture regimes in Punjab had comparatively brighter colour throughout the profile which might be due to low organic carbon content (Sidhu *et al.*, 1994). Walia and Rao (1996) noticed that the red soils in Bundelkhand region of Uttar Pradesh exhibited reddish brown to red colour (2.5 YR to 5 YR).

Sharma *et al.* (1996) stated that the soils associated with elevated topography were redder (7.5 YR) in colour which gradually became grayish (10 YR) down the slope. Dipak Dutta *et al.* (1999) reported that the redder colour of the soils in Andhra Pradesh was due to the release of iron as a result of intense weathering. The Alfisols of granitic terrain in Jabalpur district of Madhya Pradesh exhibited dark grayish brown in surface horizon but the Bt horizon showed pale brown to brownish yellow colour (Gupta *et al.*, 1999).

Dipak Sarkar *et al.* (2001) reported that the soils of the upper slopes of the toposequence in Chhotanagpur plateau were yellowish red (5 YR 4/6) in colour in the surface layer and dark red (2.5 YR 4/6) in the lower layers while the soils of lower slope of the toposequence were light brownish gray to light gray in surface horizon and gray in the lower layers.

According to Suresh Kumar *et al.* (2001) the soils of residual hills, denudational hills and pediments exhibited dark brown to dark reddish brown (7.5 YR 3/4 to 5 YR 3/4) colour whereas moderately buried pediments and valley fills had very dark grayish brown to yellowish brown (10 YR 3/2 to 10 YR 5/4) soil colour.

The colour of the soils in red and laterite region of West Bengal varied from brown to dark red (Nayak *et al.*, 2002). Dipak Sarkar *et al.* (2002) stated that the colour in the surface horizons of soils developed from shale parent material varied from very dark brown (10 YR 2/2) to dark yellowish brown (10 YR 3/4) while the sub-surface horizons were dark brown (10 YR 3/3) to yellowish red (5 YR 4/6). According to Ramprakash and Seshagiri Rao (2002) the colour of the red soils developed on granite - gneiss parent material in Krishna district of Andhra Pradesh varied from dark reddish brown (5YR 3/4) to dark brown (7.5 YR 3/4).

Inceptisols and Entisols of Shahibi basin in Haryana and Delhi varied from dark yellowish brown (10 YR 4/6) to brown (7.5 YR 4/4). The variation in the colour appears to be the function of chemical and mineralogical composition of the soils (Swarnam *et al.*, 2004). The colour of the soils in Garakahalli watershed in Karnataka varied from red to reddish brown in upland and reddish brown to grayish brown in the lowland. The strong brown colour in the surface horizons was due to high organic matter content whereas in deeper layers the dark colour may be influenced by the parent material or ferrous iron oxide (Pillai and Natarajan, 2004).

The soils located on gently sloping topography exhibited yellowish brown (10 YR 5/6) to dark red (2.5 YR 3/6) while the soils found on nearly level topography showed light yellowish brown (10 YR 6/4) to very dark grayish brown (10 YR 3/2) in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh. This variation in the soil colour was a function of chemical and mineralogical composition, topographic position, textural makeup and moisture regimes of the soils (Thangasamy *et al.*, 2005).

2.4.4 Texture

Maji and Bandyopadhyay (1995) stated that the coastal soils of Sundarbans in West Bengal having pH 4.00 to 6.00 and 6.00 to 7.50 were finer in texture (Silty clay loam to silty clay) whereas loamy sand to silty clay loam in soils having pH greater than 7.5. Ray and Reddy (1997) observed the soils buried by allochthonous material in Andhra Pradesh, in which the textural pattern of Haplusterts ranged from silty clay to loamy sand while the texture of Ustropepts varied from sandy loam to clay loam.

Sharma *et al.* (1997) reported that the texture in surface horizons of Inceptisols in North-West India varied from sandy loam to loam in udic zone and loamy to clay in ustic zone. The soils (Haplusterts) of basin floors were clay in texture while the soils (Ustropepts) on depression zones of piedmont slopes were loamy sand to sandy clay loam in texture (Bhaskar and Nagaraju, 1998). Jawahar *et al.* (1999) stated that the textural class of Theri soils in Tamil Nadu was sandy at the surface and it ranged from loamy sand through sandy clay loam to sandy clay in sub-surface. Ravender Singh and Nayak (1999) noticed that the texture of Entisols (Ustorthents) varied from sandy clay loam to sandy loam.

Raychoudhary and Sanyal (1999) identified the clay texture in Inceptisols and clay loam texture in Entisols. The soils in the upper slope of the toposequence in Chhotanagpur plateau were sandy loam to sandy clay loam while the soils in lower slopes were silty loam to clay in texture (Dipak Sarkar *et al.*, 2001). The soils occurring on upper elements of topography were clay loam to clay in texture whereas soils occurring on lower elements of topography were clay in texture (Sharma *et al.*, 2001).

Arun Kumar *et al.* (2002) stated that the soils occurring on plains had loam to sandy loam texture and recorded higher clay content than upland soils because of deposition of finer fractions from the uplands. Krishnan *et al.* (2004) stated that the Entisols of Lakshadweep islands were light textured and predominantly sandy or loamy sand and occasionally sandy loam in texture. These sandy soils were derived by physical weathering of coral limestone. The soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh showed wide textural variations (clay to sandy). This variation in soil texture was caused by parent material, topography, *in situ* weathering and translocation of clay (Thangasamy *et al.*, 2005).

2.4.5 Structure

Sand, silt and clay particles were the building blocks from which soil is constructed. The manner in which these building blocks are arranged together is called soil structure. Soil structure is just as important as soil texture in governing, how water and air move in soils. Structure fundamentally influences the suitability of soils for the growth of plant roots.

Inceptisols of North-Western Himalayan region had sub-angular blocky structure (Kaistha and Gupta, 1994). The Entisols in hills, flood plains and interdunal areas of Punjab lack structural development in the control section (Sidhu *et al.*, 1994). Elahi *et al.*, (1996) reported that the structure in the upper horizons of Inceptisols developed on Madhupur clay in Bangladesh was strong, fine to coarse and angular blocky to sub-angular blocky while the lower horizons had strong, fine to medium and sub-angular blocky to angular blocky structure.

Sharma *et al.* (1997) noticed that the structure in Inceptisols of North-West India varied from weak to moderate, fine to coarse and sub-angular blocky to angular blocky. Soils developed on basaltic terrain in Madhya Pradesh had sub-angular blocky structure in the surface horizon and angular blocky structure in the sub-surface horizons (Tamgadge *et al.*, 1999). The structure of soils in Kathiawar region of Gujarat varied from fine, weak and sub-angular blocky to medium to coarse, moderate to strong and sub-angular blocky to angular blocky (Sharma *et al.*, 2001). The structure of the soil of lower Palar-Manimuthar watershed in Tamil Nadu varies from weak to strong, fine to coarse and granular to sub-angular blocky (Arun Kumar *et al.*, 2002).

Inceptisols in Wardha district of Maharashtra showed sub-angular blocky structure (Kadao *et al.*, 2003). The structure of the Entisols of Chandauli district in Uttar Pradesh was dominantly fine, weak, granular whereas that of Inceptisols was sub-angular blocky which was a reflection of their sandy loam to sandy clay loam texture (Singh and Agrawal, 2003). Krishnan *et al.* (2004) stated that the structure of the Entisols in Lakshadweep islands developed from coral limestone was single grain with few instances of granular and sub-angular blocky in type, weak in grade and fine in size.

The structure in the cultivated soils of Neogal watershed in North-West Himalayas was granular to sub-angular blocky in surface and sub-angular blocky in sub-surface horizons (Sharma *et al.*, 2004). The Inceptisols and Entisols of southern Rajasthan had sub-angular blocky structure. However, the structure becomes massive in substratum of slightly and moderately saline layer, indicating lack of development or destruction of soil structure due to prevailing moist conditions in the soils (Sharma *et al.*, 2004).

2.4.6 Consistence

According to Mishra and Ghosh (1995) due to negligible or very small amount of expanding clay minerals in soils derived from mica - rich parent material, the consistence was not very sticky and plastic. Singh and Mishra (1996) stated that the consistence of soils in higher topographic positions was non-sticky and non-plastic whereas lower topographic positions exhibited very sticky and very plastic consistence.

Sidhu *et al.* (1998) reported that the soils (Ustipsamments) developed on sandstones exhibited hard, friable and non-sticky and non-plastic consistence while the soils (Ustochrepts) of old flood plains of Yamuna river transect showed hard, friable and slightly sticky and slightly plastic consistence. Patil *et al.* (1999) noticed that the consistence was hard (dry), firm (moist) and slightly sticky and slightly plastic (wet) in case of Entisols (Ustorthents) and hard to very hard (dry), firm to very firm (moist) and very sticky and very plastic consistence (wet) in case of Vertisols (Haplusterts). The consistence of the soils in Chhotanagpur plateau was slightly hard to hard (dry), friable to firm (moist) and slightly sticky to very sticky and non-plastic to very plastic (wet) (Dipak Sarkar *et al.*, 2001).

The dry consistence in sandy loam to loamy soils varied from soft to hard whereas loamy sand to silty clay loam soils was loose to extremely hard in Maul khad catchment of Himachal Pradesh (Sharma and Anil Kumar, 2003). The dry consistence varied from loose to hard in surface horizon and loose to very hard in sub-surface horizon in the Entisols, Inceptisols and Alfisols of Neogal watershed in North-West Himalayas (Sharma *et al.*, 2004). The

consistence of the soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh was loose to very hard (dry), loose to very firm (moist) and non-sticky to very sticky and non-plastic to very plastic (wet) (Thangasamy *et al.*, 2005).

2.5 VERTIC PROPERTIES

2.5.1 Cracks

Venkateswarlu *et al.* (1995) studied the black soils of Kandukuru division of Andhra Pradesh which were sticky and plastic exhibiting cracks of about 2 to 5 cm wide and extending up to a depth of 65 cm. Sharma *et al.* (1996) observed the cracks of 1 to 3 cm wide and 0.60 m deep in soils developed on gently sloping plain to nearly level alluvial plain of basaltic terrain.

The Haplusterts occurring in the Chitravathi river basin of Andhra Pradesh had cracks of 2.5 to 5 cm wide and extended to a depth of 20 to 50 cm while the Ustropepts of same area exhibited cracks of 1 cm wide to a depth of 30 cm (Bhaskar and Nagaraju, 1998). Gupta *et al.* (1999) stated that the presence of less than 1 cm wide cracks upto 37 cm, clay content more than 35 per cent and cambic B horizon in Garha soils necessitated its placement

under Vertic Ustochrepts. The Vertic Haplustepts of Kathiawar region of Gujarat had greater than 5 mm wide cracks through a depth of 30 cm (Sharma *et al.*, 2001). The Vertic Haplustepts occurring in the Krishna district of Andhra Pradesh exhibited 0.5 to 1 mm wide cracks upto 52 cm depth (Ramprakash and Seshagiri Rao, 2002). Vertic Haplustepts in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh showed 3 to 7 mm wide cracks extended upto 35 cm depth (Thangasamy *et al.*, 2005).

2.5.2 Slickensides

Subbaiah and Manickam (1992) noticed prominent and intersecting slickensides in Vertisols developed on different parent material. Gangapur soils (Chromic Haplusterts) of Nasik district, Maharashtra derived under semi-arid climate had 1 cm wide cracks extending upto 60 cm and also showed intersecting slickensides (Jagdish Prasad *et al.*, 1995).

Padole and Deshmukh (1998) observed well developed slickensides in the sub-surface horizons of Vertisols of Maharashtra. The soils (Haplusterts) of Chitravathi river basin of Andhra Pradesh exhibited vertic properties of intersecting

slickensides in the deeper layers and presence of wedge shaped aggregates in the second layer (Bhaskar and Nagaraju, 1998). Thick slickensides (6 to 84 cm) were observed in the Vertisols of Rajasthan. These were produced due to the abundance of smectite, high proportion of clay and deeper soil profile (Singh *et al.*, 2004). Weak, indistinct slickensides were observed in lower horizons of Vertic Haplustepts in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh (Thangasamy *et al.*, 2005).

2.6 DIAGNOSTIC HORIZONS

2.6.1 Ochric epipedon

This is a light coloured surface horizon contains less than 1 per cent organic matter and is hard or very hard and massive when dry.

Saxena (1992) noticed that the soils of Bhadurgarh, Patiala and Jabalpur had ochric epipedon and these soils were classified as Ochrepts at sub-order level. Sharma *et al.* (1993) reported that the soils of Pandgha series showed the presence of an ochric epipedon underlined by the sub-surface horizon showing the absence of rock structure for atleast half the volume.

Sen *et al.* (1997) studied the soils (Inceptisols) developed on sedimentary and metamorphic rocks of North Eastern region and reported the presence of ochric epipedon with a base saturation less than 60 per cent and included under Dystrochrept. Sharma *et al.* (1997) stated that the soils of North-West India had ochric epipedon, hence these soils were classified under Ochrepts at sub-order level. The Gondal soils of Kathiawar region of Gujarat had ochric epipedon developed over weathered basalt (Sharma *et al.*, 2001).

2.6.2 Cambic horizon

It is a coloured or structural B-horizon formed due to alteration by physical movement or by chemical weathering. The horizon is extremely variable in mineralogy because of its pedogenic youthness, occurs under widely differing environments and may develop in the presence (or) absence of fluctuating ground water.

Sen *et al.* (1996) studied the soils of Manipur valley and observed the cambic horizon as a diagnostic sub-surface horizon

in Inceptisols. Walia and Rao (1996) reported the presence of altered Bw horizon in sub-surface of red soils in Bundelkhand region where there was no clay illuviation and clay skin formation. Sharma *et al.* (1997) noticed the development of an altered structural B (cambic) horizon in Inceptisols of North-West India. Khan *et al.* (1998) studied the morphological features and other relevant properties of flood plain soils of Bangladesh, which showed little profile development with a structural B horizon (cambic).

Shivaramu *et al.* (1998) observed the cambic horizon at 0.30 to 1.60 m, 0.11 to 1.59 m and 0.07 to 0.86 m depth in Ustropepts of Hessarghatta farm near Bangalore. According to Pannu *et al.* (1999) the soils of Uchani series in Haryana had an ochric epipedon underlined by an altered B-horizon (cambic) which qualified them for the order Inceptisol. Sharma *et al.* (2001) stated that the Gondal soils of Kathiawar region of Gujarat had ochric epipedon and cambic sub-surface horizon (21 cm thick) developed over basalt.

2.6.3 Argillic horizon

A silicate clay - enriched horizon formed by illuviation of clay (or) the fine clay is carried downward by percolating waters and deposited as clay skins or cutans on ped faces and on the walls of the pores is called an argillic horizon (Sehgal, 1986).

In the Northern zone of Orissa, the pedons situated on bonded pediments had argillic horizons and were placed under Alfisols (Sahu *et al.*, 1990). According to Walia and Rao (1996) Devagan and Gonda soils showed the formation of clay enriched argillic horizon as indicated by the presence of clay cutans on ped faces. Giridhar *et al.* (1997) stated that the red soils of Komarole mandal in Andhra Pradesh were placed under Alfisols because of the presence of diagnostic argillic horizon.

Nanda *et al.* (1997) reported that the soils of Kuanria irrigation project showed increase in clay content with the presence of clay cutans in the horizon and ultimately qualified for an argillic horizon. The soils of lower outlier of Chhotanagpur plateau had illuvial horizon which contains 1.2 times more clay

than the eluvial horizon, thus qualifying for argillic sub-surface diagnostic horizon (Dipak Sarkar *et al.*, 2001). Arun Kumar *et al.* (2002) stated that the soils of Sirukudal patti and Vengalur series of lower Palar-Manimuthar watershed of Tamil Nadu were placed under Alfisols because of the presence of diagnostic argillic horizon. The Argillic horizon was formed quickly in fresh regolith summit soils of Meghalaya than in convex plateau tops where colluvium interrupts the orderly progression of soil development (Bhaskar *et al.*, 2004).

2.7 PHYSICAL PROPERTIES

2.7.1 Particle size distribution

Sand constitutes 90 per cent in soils (Psamments) of Minicoy Island, Lakshadweep (Vadivelu and Bandyopadhyay, 1997). The granulometric data revealed that the clay content of soils in Trans - Yamuna plains varied from 15.40 to 39.40 per cent and such variation could be due to change in depositional pattern as indicated by abrupt change in sand / silt ratio (Walia and Rao, 1997).

Rice growing soils (Aquepts) of upper Brahmaputra valley of Assam exhibited wide variation in particle size distribution *i.e.* content of silt 11.20 to 85.10 per cent and clay 7.70 to 60.30 per cent (Gangopadhyay *et al.*, 1998). Clay percentage in rice growing soils ranged from 26.10 to 31.30 per cent and sand content from 45.26 to 48.78 per cent whereas clay percentage in non-rice growing soils the varied from 22.42 to 27.12 per cent as compared to rice growing soils and sand contributed to 48 to 58 per cent (Pannu *et al.*, 1999).

Gravel (25 to 46 per cent) and sand (67 to 82 per cent) contents were higher in the soils of poorly managed terraces whereas silt and clay were higher in well managed terraces (Singh *et al.*, 1999). According to Verma *et al.* (2001) the soils in different landscapes showed that the sand and silt constitute major portion in mechanical composition. Particle size distribution in Alfisols of some benchmark soils of West Bengal indicated that a distinct increase in clay content in sub-surface (Bt horizons) (Nayak *et al.*, 2002). Sub-surface horizons of Neogal watershed in North-West Himalayas exhibited higher clay content as compared to surface horizons due to the illuviation process occurring during soil

development. Similarly, the illuviation process also affected the vertical distribution of silt and sand contents (Sharma *et al.*, 2004).

2.7.2 Water holding capacity

Madhusudhana Rao (1993) observed that the water holding capacity of sandy soils in Chakicharla village of Prakasam district, Andhra Pradesh ranged from 16.45 to 21.42 per cent and it was gradually decreased with depth. Water holding capacity in coastal soils of Sundarbans, West Bengal ranged from 21.40 to 37.60 per cent (Maji and Bandyopadhyay, 1995).

According to Gupta and Chara (1996) the water holding capacity was usually higher in soils on the northern aspect than in soils on southern aspect. Ravender Singh and Nayak (1999) studied the water retention characteristics of Mahi right bank canal command area of Gujarat and concluded that the water retention capacity was in the order of Vertic Haplaquepts > Typic Haplaquepts > Fluventic Ustochrepts > Typic Ustrothents.

The available water storage capacity was low (5.30 to 5.90 cm) in poorly maintained terraces as compared to well maintained terraces (11.00 to 26.30 cm) in some cultivated soils of Ramganga catchment in Uttar Pradesh (Singh *et al.*, 1999). The water holding capacity in soils of Haldi Ghati region of Rajasthan were low to medium (17.10 to 37.30 %) (Sharma *et al.*, 2001).

The moisture retention in Inceptisols and Entisols of Shahibi basin in Haryana and Delhi at 33 kPa was 8.2 to 19.00 per cent and at 1500 kPa was 3.20 to 8.89 per cent in surface horizons. The low moisture retention was due to lighter texture, low organic matter content and dominance of illite in the clay fraction (Swarnam *et al.*, 2004). The water holding capacity in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh was ranged from 13.05 to 58.99 per cent. These differences were due to the variation in the depth, clay silt and organic carbon content in the soils (Thangasamy *et al.*, 2005).

2.7.3 Bulk density and particle density

The values of bulk density varied from 1.40 to 1.80 Mg m⁻³ and showed increasing trend with depth in Kavali canal area of

Somasila project in Andhra Pradesh (Prasuna Rani *et al.*, 1991). Madhusudhana Rao (1993) studied the sandy soil profiles in Chakicharla village of Andhra Pradesh and observed that the particle density and bulk density values ranged from 2.48 to 2.65 Mg m⁻³ and 1.46 to 1.61 Mg m⁻³, respectively. The bulk density values of laterite and associated soils varied from 1.20 to 1.70 Mg m⁻³ (Bhaskar and Subbaiah, 1995).

Gurumurthy *et al.* (1996) stated that the particle density in red, black and associated soils in Giddalur mandal of Andhra Pradesh was more or less uniform and the bulk density was higher in the sub-surface horizons due to compaction of soil particles. Walia and Rao (1997) noticed that the bulk density in soils of Trans-Yamuna plains ranged from 1.46 to 1.96 Mg m⁻³ and increase of bulk density with depth might be due to enhanced compaction with depth and low organic matter. Yadav and Vyas (1998) studied the major soils (Entisols) in semi-arid eastern plains of Rajasthan and observed that the bulk density values of the soils ranging from 1.51 to 1.60 Mg m⁻³ and these values were increased with increase in depth.

The bulk density ranged from 1.40 to 1.80 Mg m⁻³ in Inceptisols and 1.40 to 1.60 Mg m⁻³ in Alfisols of granitic terrain in Jabalpur district of Madhya Pradesh (Gupta *et al.*, 1999). Jawahar *et al.* (1999) studied the red coastal sand dune soils of Tamil Nadu and reported that the bulk density varied from 1.30 to 1.95 Mg m⁻³ and particle density ranged from 2.12 to 2.97 Mg m⁻³. Singh *et al.* (1999) found that the bulk density varied from 0.83 to 1.22 Mg m⁻³ in the surface soils and increased with depth in soils of Ramganga catchment. Ramprakash and Seshagiri Rao (2002) stated that the bulk density values of red soils were higher (1.45-1.63 mg m⁻³) than black soils (1.30-1.57 mg m⁻³). Marathe *et al.* (2003) reported that the bulk density values varied from 1.46 to 1.74 Mg m⁻³ and the bulk density was also increased with increasing depth in mandarin orchards of Nagpur.

The bulk density values in banana growing soils of Wardha district of Maharashtra ranged from 1.49 to 1.79 Mg m⁻³ in Inceptisols (Kadao *et al.*, 2003). The bulk density in the soils of Maul khad catchment of Himachal Pradesh varied from 1.38 to 1.62 Mg m⁻³ in surface and 1.35 to 1.72 Mg m⁻³ in sub-surface horizons. The bulk density tended to increase with depth. The

variation in bulk density was attributed to variation in organic matter, texture *etc.* (Sharma and Anil Kumar, 2003). The bulk density in the Entisols and Inceptisols of Shahibi basin in Haryana and Delhi varied from 1.48 to 1.87 Mg m⁻³ and 1.50 to 1.69 Mg m⁻³, respectively. The higher bulk density values could be due to their coarse texture and low organic matter content (Swarnam *et al.*, 2004).

The bulk density of the soils in Sivagiri micro-watershed of Chittoor district, Andhra Pradesh varied from 1.32 Mg m⁻³ in Typic Rhodustalfs to 1.90 Mg m⁻³ in Aquic Ustorthents and the values increased with depth. The increase in bulk density with depth was due to compaction of finer particles in deeper layers caused by over head weight of the surface soils. Further, the low bulk density values of surface soils was due to high organic matter content (Thangasamy *et al.*, 2005).

2.8 PHYSICO-CHEMICAL PROPERTIES

2.8.1 Soil Reaction

The pH of the red soils ranged from strongly acidic to slightly alkaline (pH 5.0 to 8.0) (Reddy *et al.*, 1993). According to Mishra

and Ghosh (1995) soils developed from mica-rich parent material had high pH which was attributed to basic nature of parent material.

Gurumurthy *et al.* (1996) stated that the pH of soils in Giddalur mandal of Andhra Pradesh were neutral to moderately alkaline (6.8 to 9.1). Nanda *et al.* (1997) noticed that the soils of Kuanria irrigation project were neutral to slightly alkaline. Sharma *et al.* (1997) reported that the pH of surface horizons varied from neutral (pH 7.3) to alkaline (pH 8.6) whereas in the sub-surface horizons it was neutral (pH 7.1) to strongly alkaline (pH 9.7) in Inceptisols of North-West India. The pH of the soils (Entisols) of Minicoy Island, Lakshadweep varied from 7.9 to 8.7. However, the surface soil had lower pH values (7.9 to 8.0) probably due to the decomposition of organic matter (Vadivelu and Bandyopadhyay, 1997).

Tamgadge *et al.* (1999) observed that the pH of the soils (Inceptisols) on basaltic terrain in North deccan plateau of Madhya Pradesh ranged from 5.8 to 7.7. Dipak Sarkar *et al.* (2001) stated that the soils of lower outlier of Chhotanagpur plateau were

moderately acidic to neutral (4.5 to 7.0) in reaction. Rudramurthy and Dasog (2001) reported that the pH of red soils ranged from slightly acidic to slightly alkaline (5.3 to 7.3) and from neutral to strongly alkaline in black soils (7.6 to 8.7). Sharma *et al.* (2001) noticed that the soils of Kathiawar region of Gujarat were neutral to strongly alkaline (7.0 to 9.1) in reaction.

The soils of Maul khad catchment in Himachal Pradesh were acidic in reaction with pH varying from 5.1 to 5.7. The horizons with high clay content exhibited higher pH. Low pH in these soils was ascribed to combined effect of soil forming factors particularly vegetation, parent material and climate (Sharma and Anil kumar, 2003). The pH varied from slightly acidic (5.83) to moderately alkaline (8.47) in the soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh. The variation in soil pH was related to parent material, rainfall and topography. Further, the KCl-pH values were lower than the water pH values, indicating the existence of net negative charge on colloidal particals (Thangasamy *et al.*, 2005).

2.8.2 Electrical conductivity

The soils of Punjab in North-West India had low electrolyte conductivity ranging from 0.16 to 0.56 dSm⁻¹ indicating their non-saline character (Sidhu *et al.*, 1994). Mishra and Ghosh (1995) stated that the soils derived from mica-rich parent material were very low in EC values. Dhaliwal *et al.* (1996) reported that the EC of flood plain soils varied from 0.15 to 0.54 dSm⁻¹. Walia and Rao (1996) noticed that the EC of soils in Bundelkhand region of Uttar Pradesh was low (less than 0.1 dSm⁻¹) suggesting very low amount of soluble salts.

Sharma *et al.* (1997) reported that the EC values of Inceptisols in North-West India varied from 0.06 to 0.30 dSm⁻¹ indicating non-saline character. The low EC (0.08 to 0.4 dSm⁻¹) in soils of Trans-Yamuna plains indicated the low amount of soluble salts (Walia and Rao, 1997). The EC of Vertisols and Inceptisols developed from different parent materials were normal with very low (< 1 dSm⁻¹) salt content (Chinchmalatpure *et al.*, 1998).

Pannu *et al.* (1999) reported that the rice growing soils of Haryana had EC values ranging from 0.20 to 0.22 dSm⁻¹ while non-rice growing soils had 0.10 to 0.15 dSm⁻¹. Ravender Singh and Nayak (1999) stated that the EC values of Typic Ustorthents ranged from 0.10 to 0.48 dSm⁻¹. Singh *et al.* (1999) noticed that the electrical conductivity was low (0.01 to 0.27 dSm⁻¹) in soils of Ramganga catchment in Uttar Pradesh. Electrical conductivity was less in red soils (0.10 to 0.31 dSm⁻¹) as compared to their black counterparts (0.24 to 1.10 dSm⁻¹) (Rudramurthy and Dasog, 2001).

The electrical conductivity of the soils of Garakahalli watershed ranged from 0.02 to 0.20 dSm⁻¹ indicating non-saline nature of the soil. However, these soils did not show any relation with depth. This may be due to the undulating nature of the terrain coupled with free drainage conditions, which favoured the removal of released bases by the percolating and drainage water (Pillai and Natarajan, 2004). The Inceptisols and Entisols of Shahibi basin in Haryana and Delhi were non-saline with electrolyte concentration ranging from 0.18 to 0.95 dSm⁻¹ (Swarnam *et al.*, 2004). The soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh showed very low electrical

conductivity values ranging from 0.02 to 0.36 dSm⁻¹, suggesting presence of very low amount of soluble salts (Thangasamy *et al.*, 2005).

2.8.3 Calcium carbonate

Sidhu *et al.* (1994) observed variable amounts of CaCO₃ (0.00 to 7.40 per cent) in different horizons. These soils did not show any definite pattern of CaCO₃ distribution with depth. Vertisols of Maharashtra had fairly high amount of free calcium carbonate (> 10 per cent) whereas Alfisols of the same area had very low CaCO₃ (Jagdish Prasad *et al.*, 1995).

Singh *et al.* (1995) observed that the soils on hills, plateau and gently sloping plains were low in CaCO₃ (4.10 to 8.50 per cent) whereas an abrupt rise in CaCO₃ (8.50 to 11.70 per cent) and zone of CaCO₃ accumulation was observed between 0.56 to 0.80 m depth of some pedons developed on basaltic terrain indicating that pedoturbation was not sufficient to erase out the effect of old pedogenic activities. According to Singh and Mishra (1996) the CaCO₃ content in soils of Gandak command area of Bihar varied between 10.40 and 15.20 per cent.

The calcium carbonate content in Inceptisols of North-West India varied from 0 to 126 g kg⁻¹ (Sharma *et al.*, 1997). The soils of semi-arid region had the lowest available Fe than the soils of sub-humid region which might be due to higher values of CaCO₃ content (Jagdish Prasad and Gajbhiye, 1999). Verma *et al.* (2001) stated that the CaCO₃ content in Etawah district of Uttar Pradesh was varied between 5.60 and 252.00 g kg⁻¹.

The CaCO₃ content was as low as 20 mg kg⁻¹ in the Vertisols of Wardha district in Maharashtra and as high as 198 mg kg⁻¹ in the Inceptisols. The CaCO₃ content increased with depth in both Inceptisols and Vertisols (Kadao *et al.*, 2003). The upland soils of Garakahalli watershed have no free CaCO₃ while lowland soils have free CaCO₃ (Pillai and Natarajan, 2004). The CaCO₃ content in Inceptisols and Entisols of Rajasthan Varied from 30.1 to 249.1 g kg⁻¹. The calcium carbonate content of these soils increased with depth due to downward movement of calcium and its subsequent precipitation as carbonate and / or decomposition of calcium carbonate (Sharma *et al.*, 2004). The calcium carbonate content in Sivagiri micro-watershed soils of Chittoor district in Andhra Pradesh was ranged from 4.1 to 108.1 g kg⁻¹ (Thangasamy *et al.*, 2005).

2.8.4 Organic carbon

The organic carbon content of Inceptisols and Entisols of Punjab ranged from 0.04 to 0.36 per cent and 0.24 to 0.45 per cent, respectively (Saxena, 1992). The organic carbon content of Vertisols and Alfisols of Maharashtra was found to decrease from the surface downwards, indicating the maturity of the profile developed on very stable landform and the surface soils registered fairly high amount of organic carbon (Jagdish Prasad *et al.*, 1995).

Dhaliwal *et al.* (1996) stated that the organic carbon content in flood plain soils of Punjab ranged from 0.06 to 0.87 per cent. Pacharne *et al.* (1996) noticed that the organic carbon content of ferruginous soils were low to medium (2.40 to 8.60 g kg⁻¹) whereas black soils had low organic carbon (1.6 to 4.9 g kg⁻¹) in Saptadhara watershed of Nagpur district, Maharashtra. The organic carbon content was medium in surface horizons and low in sub-surface horizons of Inceptisols in North-West India (Sharma *et al.*, 1997).

Ramakrishna Prasad *et al.* (1998) stated that the organic carbon content in black and alluvial soils of Andhra Pradesh varied between 0.2 and 8.6 g kg⁻¹. The organic carbon content in the soils of upper slope varied from 0.90 to 2.80 g kg⁻¹ whereas in the soils of lower slope, it varied from 0.50 to 5.00 g kg⁻¹ (Dipak Sarkar *et al.*, 2001).

According to Suresh Kumar *et al.* (2001) the organic carbon was low (0.42 to 0.50 per cent) in soils of residual and denudational hills of Dehradun while the soils of moderately buried pediments and valley fills had medium organic carbon content (0.08 to 0.97 per cent). Dipak Sarkar *et al.* (2002) reported that the organic carbon content in the surface soils of Loktak catchment area in Manipur ranged from 24.7 to 45.4 g kg⁻¹ and decreases with depth. The organic carbon in surface horizons of banana growing soils in Wardha district of Maharashtra was more (5.5 to 8.7 mg kg⁻¹) and it decreased in sub-surface soils to a minimum of 1.4 mg kg⁻¹ (Kadao *et al.*, 2003).

The organic carbon content was low (1.0 to 5.6 g kg⁻¹) in Entisols and Inceptisols of Chandauli district, Uttar Pradesh due to the existing rice-wheat cropping system and prevailing semi-arid environment (Singh and Agrawal, 2003). The organic carbon in soils of uplands showed a regular decrease with depth while the soils in inter-hill valleys exhibited an irregular trend with depth (Bhaskar *et al.*, 2004). The organic carbon was high in the grassland soils on summits and convex plateau tops when compared to the soils on side-slopes and narrow valleys of Meghalaya (Bhaskar *et al.*, 2004).

2.9 ELECTRO-CHEMICAL PROPERTIES

2.9.1 Cation exchange capacity

The fine loamy soils in the recent flood plains of Punjab had the highest CEC while those on sand dunes had the lowest CEC (Sidhu *et al.*, 1994). Mishra and Ghosh (1995) reported that the CEC values of soils derived from mica-rich parent material varied between 6.00 and 15.90 cmol(p+) kg^{-1} soil apparently due to variation in clay and organic matter contents. Walia and Chamuah (1996) noticed that the values of CEC in proportion to their organic matter or clay content in some Inceptisols of Arunachal

Pradesh might be either due to dominance of illite and kaolinitic clays or due to formation of complexes of clay and sesquioxides with organic matter, which led to blocking of exchange sites.

Cation exchange capacity of Inceptisols in North-West India varied from 2.80 to 32.80 cmol(p+) kg⁻¹ soil. (Sharma *et al.*, 1997). According to Walia and Rao (1997) the CEC of soils varied from 10.90 to 28.40 cmol(p+) kg⁻¹ soil and the surface soil had low CEC in comparison with underlying horizons obviously due to increase in clay content. Gangopadhyay *et al.* (1998) observed the CEC of rice growing soils on upper Brahmaputra valley of Assam, as low to medium in range (2.2 to 22.8 cmol(p+)kg⁻¹ soil) and it was positively correlated with clay and organic carbon content of the soils.

Gupta *et al.* (1999) noticed that the cation exchange capacity in soils of granitic terrain in Jabalpur district of Madhya Pradesh varied from 14.70 to 55.40 cmol(p+) kg⁻¹ soil which was mostly related to the clay content of soils. CEC of the soils of lower outlier in Chhotanagpur plateau varied from 2.00 to 18.00 cmol(p+) kg⁻¹

soil (Dipak Sarkar *et al.*, 2001). Suresh Kumar *et al.* (2001) found that the CEC of soils in residual hills, denudational hills and pediments was low (11.70 to 16.37 cmol(p+) kg⁻¹ soil) whereas soils of shallow and moderately buried pediments and valley fills had moderately high CEC (15.10 to 28.20 cmol(p+) kg⁻¹ soil). The CEC of Entisols in Etawah district of Uttar Pradesh was low varying from 3.20 to 10.50 cmol(p+) kg⁻¹ soil which might be due to the presence of low CEC bearing minerals while the CEC of Inceptisols was medium (10.00 to 19.00 cmol(p+)kg⁻¹ soil) because of comparatively higher clay content (Verma *et al.*, 2001). The CEC of the Maul khad catchment soils in Himachal Pradesh, varied from 4.4 to 14.8 cmol(p+)kg⁻¹ soil and was dependent on clay and organic matter. The clay content was significantly and positively correlated with CEC (Sharma and Anil Kumar, 2003).

The CEC of the soils of Shahibi basin in Haryana and Delhi varied from 3.2 to 10.2 cmol(p+)kg⁻¹ soil and decreased with depth. Low CEC of these soils could be attributed to low content of clay and organic carbon (Swarnam *et al.*, 2004). Sharma *et al.* (2004) stated that the CEC in the soils of Neogal watershed in North

West Himalayas ranged from 4.9 to 14.3 cmol(p+) kg^{-1} soil. The difference in CEC between the soils was due to the varied type / content of soil colloids and soil pH values.

The CEC of the Garkahalli watershed soils was found to be low to medium. Maximum CEC was observed in the horizons where illuviation of clay from surface to sub-surface horizon had taken place (Pillai and Natarajan, 2004). CEC of the soils of Dindori district of Madhya Pradesh with smectitic mineralogy was higher (72 cmol(p+) kg^{-1}) as compared to the soils with mixed mineralogy (28.9 cmol(p+) kg^{-1}) (Patil and Jagdish Prasad, 2004). Thangasamy *et al.* (2005) stated that the CEC of the soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh ranged from 1.50 to 45.14 cmol(p+) kg^{-1} soil which corresponds to their clay content in the respective horizons.

2.9.2 Base saturation

Singh and Mishra (1996) noticed that the soils of Gandak command area of Bihar were highly base saturated and the cations on the exchange complex were in the order: $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{K}^+ = \text{Na}^+$. Sridhar and Ananthanarayana (1996) studied the base

saturation in two different soil orders under rice fallow profiles of Karnataka and concluded that the Inceptisols had 17.00 to 67.00 per cent and Entisols had 24.00 to 71.00 per cent base Saturation. According to Walia and Rao (1996) the base saturations of the soils in Bundelkhand region of Uttar Pradesh varied from 67.00 to 88.00 per cent except in Dystric Ustrochrept having less than 66.00 per cent. Base saturation in Epiaquepts of Banda plain region was varying from 75.00 to 89.00 per cent (Walia *et al.*, 1997). Gangopadhyay *et al.* (1998).

Dipak Sarkar *et al.* (2001) studied the soils of lower outlier of Chhotanagpur plateau and noticed that, among the exchangeable bases, Ca^{2+} was the dominant cation followed by Mg^{2+} , Na^+ and K^+ and base saturation of these soils ranged from 49.00 to 77.00 per cent. Sharma *et al.* (2001) stated that the soils of Kathiawar region of Gujarat had high base saturation with dominance of Ca^{2+} followed by Mg^{2+} on the exchange complex. The exchangeable calcium ranged from 0.1 to 8.8 c mol(p⁺)kg⁻¹ soil while exchangeable magnesium varied between 0.5 and 6.5 c mol(p⁺)kg⁻¹ soil in Entisols (Typic Ustipsamments) and Inceptisols (Typic Haplustepts) of Nellore district in Andhra Pradesh (Venkatesu *et al.*, 2002).

The per cent base saturation of the soils in upper Maul khad catchment of Himachal Pradesh ranged from 45 to 62 indicating moderate soil fertility status. Among different cations, Ca^{2+} dominated the exchange complex followed by Mg^{2+} , K^{+} and Na^{+} (Sharma and Anil Kumar, 2003). Sharma *et al.* (2004) stated that the base saturation of soils in Neogal watershed in North-West Himalayas ranged from 46 to 77 per cent and the difference in base saturation was due to varied type / content of soil colloids and soil pH values.

Pillai and Natarajan (2004) reported that the base saturation of soils was medium to high due to the low to medium amount of rainfall in Garakahalli watershed of Bangalore rural district. Among the exchangeable cations Ca^{2+} dominates the exchange complex followed by Mg^{2+} which dominates over Na^{+} in the Entisols and Inceptisols of Rajasthan. Further, it was observed that with the increase in the finer fractions in the soil there was a corresponding increase in the content of exchangeable bases (Sharma *et al.*, 2004). The Entisols and Inceptisols of Shahibi basin were highly base saturated ranging from 75.90 to 89.30 and from 80.80 to 94.30 per cent, respectively. Further, the exchange complex was dominated by Ca^{2+} followed by Mg^{2+} , Na^{+} and K^{+} (Swarnam *et al.*, 2004).

The exchange complex of Inceptisols and Mollisols in Dindori district of Madhya Pradesh were dominated by Ca^{2+} followed by Mg^{2+} , K^+ and Na^+ . Further, high and low exchangeable Ca and Mg in Typic Haplustolls and Typic Haplustepts, respectively was attributed to their parent materials and the higher exchangeable Ca in the surface soil may be due to redistribution of Ca by tree species (Patil and Jagdish Prasad, 2004). The base saturation in the soils varied from 31.53 to 92.77 per cent and exchangeable bases were in the order of $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ > \text{K}^+$ in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh (Thangasamy *et al.*, 2005).

2.9.3 Silica and Sesquioxide

Singh *et al.* (1993) observed that the sedentary soils developed on granite-gneiss were highly siliceous (SiO_2 upto 79 per cent) and high SiO_2 content indicated the influence of acidic parent rocks. Mishra and Ghosh (1995) studied the soils derived from mica-rich parent material and reported that the silica content (59 to 69 per cent) increased with depth and sesquioxide content (3.45 to 30.75 per cent) decreased with depth. SiO_2 content was much higher than Al_2O_3 and thus indicating that the process of silication was operating in these soils.

Walia and Rao (1996) noticed that the SiO₂ content in soils of Bundelkhand region of Uttar Pradesh ranged from 59.00 to 76.00 per cent and such variations were due to the nature of parent material. But, the soils developed from shale were less siliceous. Silica was the most dominant element (upto 83 per cent) in benchmark soils (Entisols) of flood plains in Bangladesh (Khan *et al.*, 1997).

According to Walia and Rao (1997) the soils of Trans - Yamuna plains were siliceous in nature and SiO₂ content varied from 59.70 to 76.80 per cent. The SiO₂ content of coastal sand dunal soils of Tamil Nadu varied from 74.53 to 93.88 per cent (Jawahar *et al.*, 1999). According to Ramalakshmi *et al.* (2001) Psamments had more silica and less sesquioxide content than Haplustepts and Haplusterts and exhibited increasing trend with depth in Bapatla - Karlapalem region of Guntur district in Andhra Pradesh. Ramprakash and Seshagiri Rao (2002) stated that the soils developed from granite-gneissic parent material mixed with sandstone and quartzite, were more siliceous (66.20-74.30%) than the soils originated from granite-gneissic complex mixed with schist and calcareous murrum (54.83-63.96%).

2.10 FERTILITY STATUS

2.10.1 Total and available macronutrients

The contents of available P and K increased along the descending slope and also showed same depth function in the profile. Further, the surface soils were quite rich in K and P contents and this might be due to management practices followed in the cultivated soils (Gaikawad *et al.*, 1974). The total N, P and K content of red and associated soils in Nellore district of Andhra Pradesh varied from 0.019 to 0.053, 0.006 to 0.057 and 0.10 to 0.41 per cent, respectively. The available N, P and K status ranged between 82 to 95, 1.40 to 11.00 and 148 to 345 mg kg⁻¹ soil, respectively (Prasuna Rani *et al.*, 1992).

Singh *et al.* (1993) reported that the total nitrogen content of the soils developed from granite-gneiss and Mahananda alluvium ranged from 0.10 to 0.72 per cent. The soils of Sundarbans were deficient in available nitrogen, low to high in available phosphorus and high in available potassium (Maji and Bandyopadhyay, 1995).

Gurumurthy *et al.* (1996) stated that red, black and associated soils of Giddalur mandal of Andhra Pradesh were low in available nitrogen (42 to 105 mg kg⁻¹) and phosphorus (1.40 to 11.50 mg kg⁻¹) while potassium (73 to 210 mg kg⁻¹) was medium to high and the available sulphur content was sufficient (5.00 to 21.20 mg kg⁻¹) in surface soils. Sharma and Gangwar (1997) observed that the total sulphur content in Inceptisols of Moradabad district in Uttar Pradesh ranged from 167 to 917 mg kg⁻¹ soil and also noticed negative correlation between total sulphur and pH and also between total sulphur and electrical conductivity. Invariably the surface soils had higher concentration of water soluble and exchangeable K than sub-surface soils in Karnataka (Hirekurabar *et al.*, 2000). The available N, P and K content in the soils of Loktak catchment area of Manipur varied from 538 to 1035, 11.6 to 46.0 and 106 to 318 kg ha⁻¹, respectively (Dipak Sarkar *et al.*, 2002). Rakesh Kumar *et al.* (2002) observed that the total sulphur content in Entisols ranged from 282 to 470 mg kg⁻¹ while it varied from 141 to 723 mg kg⁻¹ in Alfisols of Jharkhand. The available K content showed an irregular trend of distribution with soil depth and was significantly and positively correlated with clay content as K availability is largely controlled by clay minerals (Sharma and Anil Kumar, 2003).

Thangasamy *et al.* (2005) stated that the available N, P, K and S contents varied from 59 to 502 kg ha⁻¹, 4.5 to 29.3 kg ha⁻¹, 22 to 212 kg ha⁻¹ and 12.50 to 35.20 mg kg⁻¹, respectively, in the soils of Sivagiri micro-watershed of Chittoor district in Andhra Pradesh. These nutrients were more in the surface horizons than in the sub-surface horizons.

2.10.2 Total and available micronutrients

The available Zn and Fe were deficient in red, black and associated soils in Giddalur mandal of Andhra Pradesh while Cu and Mn were sufficient (Gurumurthy *et al.*, 1996). The soils developed from basaltic rocks had the highest amount of total micronutrients whereas one derived on granitic granodiorite was the poorest and also stated that clay content and organic carbon were positively correlated with these micronutrients (Murthy *et al.*, 1997).

Dipak Sarkar *et al.* (2000) stated that some Inceptisols and Entisols of Madhubani district, Bihar had the highest content of available Zn, Cu, Fe and Mn in surface layers which might be due

to their regular addition through plant residues, organic manures and fertilizers. The total micronutrient contents such as Zn, Fe, Cu and Mn were ranged from 10.2 to 43.7 mg kg⁻¹, 1.0 to 1.8 per cent, 5.2 to 24.7 mg kg⁻¹ and 70.0 to 230.0 mg kg⁻¹, respectively. However, the available micronutrients such as Zn, Fe, Cu and Mn were also ranged from 0.32 to 1.84, 6.0 to 35.6, 0.25 to 19.8 and 7.2 to 62.4 mg kg⁻¹, respectively in Entisols and Inceptisols of Nellore district in Andhra Pradesh (Venkatesu *et al.*, 2002). Dipak Sarkar *et al.* (2002) stated that the available Cu and Zn were deficient in the soils of Loktak catchment area of Manipur while Fe and Mn were sufficient.

Patil and Jagadish Prasad (2004) stated that the *sal* supporting soils of Dindori district, Madhya Pradesh were rich in DTPA extractable iron and manganese and the status of copper and zinc were above the critical limits. The surface horizons in upland soils of Meghalaya have sufficient amounts of DTPA extractable iron, manganese, copper and zinc whereas high concentration of iron and manganese were noticed in the valleys (Bhaskar *et al.*, 2004). Available copper and manganese were adequate whereas 44.00 and 20.00 per cent of the soils were rated

as deficient in available zinc and iron, respectively. The micronutrients increased with increase in organic carbon and decreased with increase in pH and CaCO_3 in soils of Telangana region of Andhra Pradesh (Satyavathi and Suryanarayan Reddy, 2004).

The available iron (0.48 to 7.74 mg kg⁻¹ soil) was deficient whereas available Cu (0.28 to 1.68 mg kg⁻¹ soil) and Mn (3.68 to 17.24 mg kg⁻¹ soil) were well supplied in both surface and sub-surface horizons. However, the available Zn was sufficient in surface horizons (0.42 to 0.94 mg kg⁻¹ soil) and deficient in sub-surface horizons (0.10 to 0.96 mg kg⁻¹ soil) in soils of Sivagiri micro-watershed of Chittoor district in Andhra Pradesh (Thangasamy *et al.*, 2005).

A survey conducted in black and red soils of Karnataka revealed that the soils were sufficient with respect to iron and manganese and distribution of zinc and copper did not follow any definite pattern (Krishna Murthy and Srinivasa Murthy, 2005).

2.11 MINERALOGY OF CLAYS

Seshagiri Rao and Chatterjee (1990) reported the dominance of kaolinite in the clay fraction of Ustalfs in Telangana region of Andhra Pradesh. The red soils in Rajmahal trap of Bihar was dominated by kaolinite, mica and smectite with small amounts of vermiculite and mica-smectite intergrades (Tiwarly and Mishra, 1992). Clay mineralogical investigation of soils on Deccan basalt in the western ghats of India indicated that interstratified smectite - kaolinite (Sm/K) was dominant in red soils whereas smectite was dominant in black soils (Bhattacharyya *et al.*, 1993).

Mica was found to be the dominant clay mineral in red soils of Kandukur division in Prakasam district of Andhra Pradesh (Jagannadham *et al.*, 1995). Gurumurthy *et al.* (1996) stated that the mica and montmorillonite were the dominant clay minerals in red and black soils, respectively in Giddalur mandal of Prakasam district in Andhra Pradesh. According to Kaushal *et al.* (1996) the soil clays of Entisols / Inceptisols under forest in temperate zone of Himalayas were dominated by illite followed by kaolinite, interstratified minerals and chlorite.

The Inceptisols and Vertisols near Saptadhara watershed area were dominated by smectite with sub-ordinate amounts of kaolinite (Pacharne *et al.*, 1996). Sharma *et al.* (1997) reported that the illite was the most dominant clay mineral followed by kaolinite, smectite and chlorite in the Inceptisols of North-West India. Giridhar *et al.* (1998) stated that the red soils of Komarole mandal of Andhra Pradesh developed from granitic parent material contained kaolinitic type of clay mineral.

Sangwan *et al.* (1998) studied the clay mineralogy of Entisols / Inceptisols of Satluj - Yamuna divide in the north Indian plains. All the soils were dominated by mica (> 55 per cent) due to its inheritance from the parent material. Other clay minerals associated were chlorite, smectite and mixed layer minerals. Mall and Mishra (2000) reported that the clays in Alfisols of northern Bihar indicated the characteristic peaks of mica, kaolinite, vermiculite, chlorite, quartz, feldspar and intergrades. Ramesh *et al.* (2002) reported the dominance of kaolinite in the clay fraction of Typic Haplustalf, Typic Rhodustalf and Typic Haplustepts, silica in case of Aquic Ustipsamments and smectite in case of Vertic Haplustepts.

The X-ray diffractograms showed the presence of illite, kaolinite and smectite in soils of Shahibi basin in Haryana and Delhi. The predominance of illite and Kaolinite in clay fraction is responsible for low CEC and poor nutrient retention characteristics of these soils (Swarnam *et al.*, 2004). The X-ray diffraction analysis of *sal* supporting soils in Dindori district of Madhya Pradesh indicated the presence of smectite as the dominant clay mineral followed by Kaolinite, mica and feldspar (Patil and Jagdish Prasad, 2004). Thangasamy *et al.* (2004) reported that the semi-quantitative estimates of clay fractions based on relative areas under corresponding peaks indicated that most of the soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh were dominated by smectite followed by kaolinite and mica whereas some soils are dominated by kaolinite followed by considerable amounts of smectite and mica. Feldspar and quartz were present in traces.

2.12 CLASSIFICATION

Saxena (1992) classified the soils of recent flood plain and meadow plain soils of Punjab as Typic Ustipsamments. Madhusudhana Rao (1993) classified the sandy soils of

Chakicharla village of Prakasam district, Andhra Pradesh as Typic Ustipsamments which do not have any diagnostic horizon and had ustic soil moisture regime.

Sidhu *et al.* (1994) classified the soils of Punjab in North-West India into Ustorthents, Ustifluvents, Ustipsamments, Torripsamments and Torriorthents. Ahuja *et al.* (1996) classified the soils in sand dunal toposequence of Haryana as Entisols and Aridisols. The flood plain soils of Punjab were classified into Entisols at order level and Orthents, Fluvents and Psamments at sub-order level (Dhaliwal *et al.*, 1996).

Red, black and associated soils of Giddalur mandal in Andhra Pradesh were grouped as Calcic Ustochrepts, Typic Haplustalfs, Chromic Calciusterts, Typic Rhodustalfs and Vertic Ustochrepts (Gurumurthy *et al.*, 1996). According to Sharma *et al.* (1996) the soils were classified taxonomically into Lithic / Typic Ustorthents, Typic Haplusterts and Typic Ustifluvents. Singh and Mishra (1996) grouped the soils in Gandak command area of Bihar as Typic Ustorthents, Typic Eutrochrepts, Typic Haplustalfs and Typic Hapludalfs.

The red soils in Bundelkhand region of Uttar Pradesh were classified into Inceptisols and Alfisols (Walia and Rao, 1996). Gupta *et al.* (1999) classified the soils of granitic terrain in Jabalpur of Madhya Pradesh into Typic Haplusterts, Vertic Ustochrepts and Typic Haplustalfs. The soils of different landscapes in Etawah district of Uttar Pradesh were grouped into Typic Ustipsamments, Typic Haplustepts and Typic Ustorthents (Verma *et al.*, 2001).

Dipak Sarkar *et al.* (2002) classified the soils of Loktak catchment area of Manipur into Inceptisols due to presence of diagnostic cambic horizon. Ramprakash and Seshagiri Rao (2002) classified the soils of Krishna district of Andhra Pradesh into Vertic Haplustepts, Lithic Halplustepts and Typic Halplusterts. According to Marathe *et al.* (2003) the soils of mandarin orchards in Nagpur were classified into Vertic Haplustepts, Typic Haplustepts, Typic Ustorthents and Typic Haplusterts.

The soils on fluvio – glacial terraces under croplands and tea gardens in upper Maul khad catchment were classified as Inceptisols and Alfisols while those on hill slopes under pine forests and pastures as Entisols (Sharma and Anil Kumar, 2003).

The cultivated soils in low hills zone of Neogal watershed were classified into Entisol and Inceptisols while those of mid hills zone belong to Entisols, Inceptisols and Alfisols (Sharma *et al.*, 2004). Sharma *et al.* (2004) classified the salt-affected soils of southern Rajasthan into Typic Haplustepts, Typic Calciustepts and Aridic Ustorthents. Bhaskar *et al.* (2004) studied the soils on hillslopes of Meghalaya and stated that the soils in uplands were classified into subgroups of Ultisols and Entisols but the soils in valleys were classified into the sub-groups of Inceptisols.

2.13 LAND CAPABILITY CLASSIFICATION

Sidhu *et al.* (1994) reported that the land capability sub-class of Ustorthents varied from VIe to VIIe due to severe erosion while Ustic Torriorthents had IIe land capability sub-class due to moderate erosion in Punjab. Sharma *et al.* (1996) reported that the

soils developed from basaltic rocks were classified into IIs, IIIs, IVes and VIes capability sub-classes. Singh and Mishra (1996) stated that the soils in Gandak command area of Bihar were classified into different land capability sub-classes such as I, IIs and IIw. The soils of micro-watershed of Wunna catchment near Nagpur were grouped into different land capability sub-classes *viz.*, IIs, IIIs, IIIw and IVes (Chinchmalatpure *et al.*, 1998). The soils were classified into different land capability classes and sub-classes based on their limitations and potentials. However, the soils of Shiwalik hills were classified under IVt, VI and VIIt land capability sub-classes whereas the soils of upper pediment plains qualified for sub-classes IIIt, IIw and IIe (Patel *et al.*, 2001).

The high hill soils such as Humic Dystrudepts and Humic Hapludults were placed in the land capability sub-class VIes due to very steep slope, very severe erosion, low moisture holding capacity and high soil acidity while the medium hill soils (Typic Haplohumults) were classified under land capability sub-class IVes due to moderately steep slope, severe erosion, low moisture holding capacity, gravelly or concretionary subsoil and high soil acidity. Further, the foot hill soils (Typic Palehumults) and gently

sloping plain soils (Aquic Haplohumults) were classified into capability sub-classes IIIes and IIsw, respectively due to their limitations (Dipak Sarkar *et al.*, 2002).

Esther Shekinah *et al.* (2004) classified the soils of Sahaspur block in Uttaranchal into six land capability classes *viz.*, II, III, IV, VI, VII and VIII. Krishnan *et al.* (2004) studied the soils of Lakshadweep islands and stated that 15 per cent of the lands can be classified as fairly good lands with soil limitations (IVs), 15 per cent of lands with soil and drainage limitations (IVsw) and 13 per cent of lands as lands suitable only for forestry, grazing and recreation (VIs). Sharma *et al.* (2004) studied that the soils of Neogal watershed area in North-West Himalayas were classified into land capability sub-classes IIIe and III. The soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh have been classified into three land capability sub-classes *i.e.* IIs, IIIes, IIIw and IVs (Thangasamy *et al.*, 2005).

CHAPTER - III

MATERIALS AND METHODS

The present investigation was taken up with the objectives of studying morphology and taxonomy of soils in Ramachandrapuram mandal of Chittoor district, Andhra Pradesh. The Ramachandrapuram mandal has a total geographical area of about 7455.33 ha and comprises of ten revenue villages namely Ramachandrapuram, C.Ramapuram, Nennuru, Sorakayalapalem, Gangireddipalli, Sanjeevarayapuram, C.K.Palli, Nethakuppam, Kuppambadur and Anupalli. The materials used and methods employed in studying the morphology and taxonomy of soils are described under the following heads.

3.1 COLLECTION OF PROFILE SAMPLES

Seven master profiles (Pedons) were arranged in the Ramachandrapuram mandal representing all types of soils by taking into consideration the geology, climatic conditions, geomorphic characters and other related pedological information pertaining to the study area.

Each pedon was described for morphological characters as per the guidelines laid down in U.S.D.A. Soil Survey Manual (Soil Survey Staff, 1951). The detailed morphological description for all the seven pedons studied in the field was furnished in Appendix A. Horizon-wise soil samples were collected from each pedon for laboratory studies.

3.1.1. Control Section

The soil sample from each pedon was collected in the control section (25-100 cm). These samples were called control section samples (Soil Survey Staff, 1999) and the same were utilised for the clay separation and X-ray diffraction analysis.

3.2 COLLECTION OF SURFACE SOIL SAMPLES

In each revenue village of the mandal, an area covering 6 to 8 hectares of land visually uniform was taken as an unit and representative soil samples (@ 8 samples per village) were collected covering all types of soils. Totally, eighty surface samples (0-20 cm depth) were collected during the summer months of 2004 when the fields were dry and fallow. These surface soil samples

were collected by adopting the procedure given by Jackson (1973). The particulars of these surface soil samples were given in Appendix B.

3.3. PROCESSING OF SOIL SAMPLES

Both profile and surface soil samples were air dried under shade, ground with wooden mallet, sieved through a 2 mm sieve and preserved in polyethylene bags for laboratory analysis.

3.4 LABORATORY ANALYSIS

3.4.1 Physical Properties

3.4.1.1 *Soil colour*

Munsell's colour notation of Hue, Value and Chroma were observed for both air dried and moist profile soil samples (Soil Survey Staff, 1951).

3.4.1.2 *Soil density*

Bulk density in profile soil samples was determined by clod method (Singh, 1980) whereas for sandy soils, core sampler method was followed (Black and Hartge, 1986). Particle density for

profile soil samples was determined by specific gravity bottle method (Black and Hartge, 1986).

3.4.1.3 Particle size analysis

The particle size analysis was carried out in profile soil samples by the International pipette method. Different U.S.D.A textural fractions were estimated and expressed as percentages of sand (2.00 - 0.05 mm), silt (0.05 - 0.002 mm) and clay (<0.002 mm) on CaCO₃ free basis (Piper, 1966).

3.4.1.4 Water holding capacity, pore space and volume expansion

The physical constants such as water holding capacity, pore space and volume expansion in the profile soil samples were determined by following Keen Raczkowski's method as described by Sankaram (1966).

3.4.1.5 Loss on Ignition (LOI)

This was estimated in profile soil samples as per the procedure given by Piper (1966).

3.4.2 Physico-chemical properties

3.4.2.1 *Soil reaction (pH)*

pH of the profile soil samples was determined in 1:2.5 soil water suspension and 1:2.5 soil, 1 *N* KCl suspension by using Digisun digital pH meter (Jackson, 1973). pH of the surface soil samples was also determined in 1:2.5 soil water suspension by using Digisun digital pH meter (Jackson, 1973).

3.4.2.2 *Electrical conductivity (EC)*

The electrical conductivity for profile and surface soil samples was determined in saturation extract by using Systronics conductivity bridge 305 (Jackson, 1973).

3.4.2.3 *Organic carbon (OC)*

Organic carbon content of profile and surface soil samples was estimated by Walkley and Black's wet oxidation method as outlined by Jackson (1973).

3.4.2.4 Free calcium carbonate (CaCO_3)

The free calcium carbonate content of profile soil samples was determined by treating the soil with a known volume of standard HCl and back titrating the unused acid with standard alkali using bromothymol blue as an indicator (Piper, 1966).

3.4.2.5 Cation exchange capacity (CEC)

The cation exchange capacity of the profile soil samples was determined by saturating a known weight of soil with 1 *N* sodium acetate (pH 8.2). The excess sodium acetate was leached with 95 per cent ethanol. The adsorbed sodium was displaced with 1 *N* neutral ammonium acetate (pH 7.0). The concentration of the sodium in the leachate was determined by aspirating directly into the flame photometer (Systronics flame photometer 128). The CEC was calculated and expressed as cmol (p+) kg^{-1} soil (Bower *et al.*, 1952).

3.4.2.6 Exchangeable cations

The profile soil samples were pre-treated with 95 per cent ethanol to remove water soluble cations and the exchangeable cations were estimated by extracting the soil with 1 *N* neutral

ammonium acetate. The exchangeable sodium and potassium were determined by aspirating the leachate directly into the flame photometer (Systronics flame photometer 128). The exchangeable calcium and magnesium were determined by versenate method. The concentration of exchangeable cations Ca^{2+} , Mg^{2+} , K^{+} and Na^{+} were expressed in cmol (p+) kg^{-1} soil (Chopra and Kanwar, 1991).

3.4.3 Chemical Properties

3.4.3.1 *Preparation of acid extract for total nutrients*

One gram of oven dried soil sample was transferred into a 150 ml Erlenmeyer flask to which 20 ml of concentrated nitric acid was added and small funnel was placed over the Erlenmeyer flask to prevent rapid evaporation of acid. The contents were heated on a hot plate to oxidize the organic matter. Then 10 ml of 60 per cent perchloric acid was added and the digestion was continued until dense white fumes appeared. A little quantity of perchloric acid was added to wash down the sides of the flask and the heating was continued for another 15 minutes to dehydrate the silica. The residue was dissolved in 25-30 ml of warm double distilled water and filtered through Whatman number 42 filter paper and the filtrate was collected in 250 ml volumetric flask. The residue was washed with 0.1 N HCl and finally the volume was made upto 250 ml (Hesse, 1971).

3.4.3.1.1 Silica (SiO_2)

The residue left, over the filter paper was washed with warm distilled water for free of chlorides. Then the residue along with the filter paper was transferred to a silica crucible and then ignited in a muffle furnace. The crucible along with the residue was cooled in a desiccator and then weighed. From the weight of the residue, the percentage of SiO_2 was calculated (Hesse, 1971).

3.4.3.1.2 Sesquioxides (R_2O_3)

100 ml of acid extract was taken in a 250 ml beaker and it was boiled on a water bath for 5 minutes. A red coloured precipitate of iron and aluminium was obtained by adding ammonium hydroxide in the presence of ammonium chloride. The precipitate was washed with warm distilled water till free of chlorides. The residue along with the filter paper was dried, ignited and cooled in a desiccator and weighed. The results were expressed as per cent sesquioxides (Hesse, 1971).

3.4.3.1.3 Iron oxide (Fe_2O_3)

The concentration of iron was determined by aspirating silica free acid extract into atomic absorption spectrophotometer (ECIL AAS 4127) and the results were expressed as per cent Fe_2O_3 (Hesse, 1971).

3.4.3.1.4 Alumina (Al_2O_3)

This was determined by deducting the Fe_2O_3 content from the total content of sesquioxides.

3.4.3.1.5 Calcium

Total calcium was estimated by versenate titration by taking a suitable aliquot of sesquioxide free acid extract using murexide as an indicator in the presence of 16 per cent NaOH. The results were expressed as per cent CaO (Chopra and Kanwar, 1991).

3.4.3.1.6 Magnesium

A combined estimation of calcium and magnesium was carried out in the same sesquioxide free acid extract by versenate titration using ammonium hydroxide and ammonium chloride

buffer and Eriochrome black-T indicator. Magnesium titre value was obtained by subtracting the calcium titre value from the combined estimation of calcium and magnesium. The results were expressed as per cent MgO (Chopra and Kanwar, 1991).

3.4.3.1.7 Sodium

Sodium was estimated in nitric and perchloric acid extract directly by aspirating into the flame photometer (Systronics flame photometer 128) and the results were expressed as per cent Na₂O (Jackson, 1973).

3.4.3.2 Total macronutrients

3.4.3.2.1 Nitrogen

Total nitrogen in profile soil samples was estimated by modified kjeldahl method using sulphuric salicylic acid mixture (Hesse, 1971).

3.4.3.2.2 Phosphorus

Total phosphorus content in profile soil samples was determined by perchloric acid digestion method as described by Jackson (1973).

3.4.3.2.3 Potassium

Total potassium in the acid extract was estimated by aspirating the extract into the flame photometer (Systronics flame photometer 128) (Jackson, 1973).

3.4.3.2.4 Sulphur

Total sulphur in the profile soil samples was extracted with diacid (Hesse, 1971) and estimated by turbidimetric method (Cottenie *et al.*, 1979).

3.4.3.3 Total micronutrients

The acid extract was directly aspirated into atomic absorption spectrophotometer (ECIL AAS 4127) for the determination of total Zn, Cu, Fe and Mn. The results were expressed in mg kg⁻¹ soil (Hesse, 1971).

3.4.3.4 Available macronutrients

The surface soil samples were analysed for available macronutrients (N, P, K and S).

3.4.3.4.1 Nitrogen

The available nitrogen was estimated by the alkaline potassium permanganate method as described by Subbiah and Asija (1956).

3.4.3.4.2 Phosphorus

The available phosphorus content of soil was extracted by using Olsen's extractant as described by Olsen *et al.* (1954) and phosphorus in the extract was determined by Murphy and Riley method (using ascorbic acid as a reducing agent) as described by Watanabe and Olsen (1965) using spectrophotometer (Jasco V-530 UV/ Visible spectrophotometer) at 660 nm wavelength.

3.4.3.4.3 Potassium

Potassium in the soils was extracted by employing neutral normal ammonium acetate and determined by aspirating the extract into the flame photometer (Systronics flame photometer 128) (Jackson, 1973).

3.4.3.4.4 Sulphur

Available sulphur in the soil sample was extracted with 0.15 per cent $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ (Williams and Steinbergs, 1959) and estimated by turbidimetric method (Cottenie *et al.*, 1979).

3.4.3.5 Available micronutrients in surface soil samples

Twenty grams of soil was shaken with 40 ml of DTPA extractant of pH 7.3 for 2 hours. The contents were filtered and in the filtrate zinc, copper, iron and manganese were determined by using atomic absorption spectrophotometer (ECIL AAS 4127) with the following specifications.

Nutrient	Wave length (nm)	Optimum light (milli amperes)
Fe	248.3	10
Mn	279.5	5
Zn	213.8	10
Cu	324.8	5

The results were expressed in mg kg^{-1} soil (Lindsay and Norvell, 1978).

3.5 RATINGS FOR SURFACE SOIL SAMPLES AND COMPUTATION OF NUTRIENT INDICES

The surface soil samples were classified into low, medium and high categories as per the limits suggested by Muhr *et al.* (1965) for available N, P and K and organic carbon. Available sulphur was classified based on the critical limits proposed by Tandon (1991). In respect of available micro nutrients, the ratings given by Lindsay and Norvell (1978) were followed.

Nutrient indices for available N, P and K were worked out as per the following formula given by Parker *et al.* (1951).

$$\text{Nutrient Index} = \frac{\text{Number of samples under low category} \times 1 + \text{Number of samples under medium category} \times 2 + \text{Number of samples under high category} \times 3}{\text{Total number of samples}}$$

The nutrient indices, so computed were classified as low, medium and high as per the following ratings proposed by Ramamoorthy and Bajaj (1969).

Nutrient Index	Category
< 1.67	Low
1.67-2.33	Medium
> 2.33	High

3.5.1 Ratings for organic carbon and available N, P and K

Sl. No.	Nutrient	Low	Medium	High
1.	Organic Carbon (%)	< 0.5	0.5-0.75	>0.75
2.	Available N (kg ha ⁻¹)	<280	280-560	>560
3.	Available P (kg ha ⁻¹)	<10	10-24.6	>24.6
4.	Available K (kg ha ⁻¹)	<108	108-280	>280

3.5.2 Ratings for available sulphur

Sufficient	>	10 mg kg ⁻¹ soil
Deficient	<	10 mg kg ⁻¹ soil

3.5.3 Ratings for available cationic micronutrients

Available cationic micronutrient	Critical Limits (mg kg ⁻¹ soil)
Copper	0.2
Iron	4.5
Manganese	1.2
Zinc	0.6

3.6 CLAY MINERALOGY

3.6.1 Clay Separation

Clay in the profile soil sample collected from the control section of each pedon was separated by following the procedure outlined by Jackson (1969).

Twenty grams of soil was taken into a 500 ml beaker to which 200 ml of 1 *N* sodium acetate (pH 5.0) was added. The suspension was digested for 30 minutes on a water bath with intermittent stirring to destroy the carbonates. The clear supernatant liquid was siphoned out and this procedure was repeated once again for black and calcareous soils. Then the suspension was treated with 5 ml of 30 per cent hydrogen peroxide and allowed for digestion overnight. The digestion was continued 2-4 hours on a water bath by adding 10 ml more of hydrogen peroxide for complete oxidation of organic matter. Later, the suspension was evaporated to thin paste. Once again the contents in the beaker were stirred with 100 ml of sodium acetate (pH 7.0) to remove the soluble cations released from the organic matter. Then the suspension was subjected to CBD treatment to destroy the iron oxides. To achieve this, the suspension was treated with 40 ml of 0.3 *M* sodium citrate solution followed by 5 ml of 1 *M* sodium bicarbonate and heated on water bath to 70-80°C. Then one gram of solid sodium dithionite salt was added and stirred well and heating was continued for further 15-20

minutes. Saturated NaCl solution of about 10 ml was added to promote flocculation. The supernatant liquid was siphoned out after settling, then the beaker was filled with distilled water. This process was repeated until the contents in the beaker remain in dispersed state. The suspension was stirred with an electrical stirrer and transferred to sedimentation cylinder and the volume was made upto 1000 ml. The contents were allowed to settle for specific time (6 hours and 20 minutes) and top layer was siphoned out upto 10 cm depth into a bottle and stored as sodium clay suspension after adding suitable quantity of sodium chloride.

3.6.2 Preparation of K-saturated Clay

Suitable quantity of sodium clay suspension was transferred to a centrifuge tube and 30 ml of 1 N KCl solution was added. The contents were centrifuged for 5 minutes at 1500 rpm after shaking continuously for 5 minutes. This treatment was repeated twice. To remove the excess of potassium, the sample was washed once with distilled water, twice with methanol and once with acetone. The clay was transferred to a bottle using required quantity of distilled water to make 2 per cent clay suspension.

3.6.3 Preparation of Ca-saturated Clay

Calcium saturated clay was prepared in the same way as K-saturated clay using 1 *N* CaCl₂ solution instead of KCl solution.

3.6.4 Preparation of K and Ca-saturated clay slides

The slides of K and Ca-saturated clay were prepared by spreading 1 ml of 2 per cent clay suspension (Ca and K saturated separately) uniformly on clean microscopic slides and allowing them to dry at room temperature.

Thus the parallel oriented clay slides were prepared with the following treatments.

1. Ca-saturated clay at room temperature (25°C).
2. Ca-saturated ethylene glycol solvated clay.
3. K-saturated clay at room temperature (25°C).
4. K-saturated clay heated to 110°C.
5. K-saturated clay heated to 300°C.
6. K-saturated clay heated to 550°C.

3.6.5 X-ray diffraction analysis

The X-ray diffraction analysis was carried out on Phillips X'pert Pro PW 3040/60 XRD machine with the following scanning details

Current	-	45 mA 40 Kv
Scanning speed	-	2°2 θ minute ⁻¹
Radiation	-	Cu K α

3.7 SOIL CLASSIFICATION

A set of soil properties are diagnostic for differentiation of pedons. The differentiating characters are the soil properties that can be observed in the field or measured in the laboratory or can be inferred in the field. Some diagnostic soil horizons, both surface and sub-surface, soil moisture regimes, soil temperature regimes and physical, physico-chemical and chemical properties of soils determined in the present study were used as criteria for classifying the soils. The soils of Ramachandrapuram mandal were classified into different orders, sub-orders, great groups, sub-groups, families and finally into tentative series as per USDA Soil Taxonomy (Soil Survey Staff, 1998).

3.8 LAND CAPABILITY CLASSIFICATION

The land capability classes were fixed to the soils of Ramachandrapuram mandal based on their potentialities and limitations for sustained productivity by following USDA land capability classification (Klingebiel and Montgomery, 1966).

Land capability classification is an interpretative grouping of soils mainly based on their inherent soil characteristics, external land features and environmental factors that limits the use of land for agriculture. There are eight land capability classes designated by Roman letters from I to VIII in the increasing order of hazards and limitations in the use of land. Classes I to IV are suitable for agriculture under proper and specific management. Classes V to VII are not suitable for arable agriculture but suitable for pasture or forestry. Class VIII is suited only for wild life sanctuary and recreational purposes.

Land capability sub-classes are soil groups within a land capability class that were designated by small letters like 'e' for erosion, 's' for soil limitations, c for climatic limitations and 'w' for

wetness. Land capability units are grouping of one or more soil mapping units having similar potentials, limitations and responses to management.

3.9 STATISTICAL ANALYSIS

Various soil properties were tested for their correlation with one another as per the procedure described by Gomez and Gomez (1984).

CHAPTER - IV

RESULTS

4.1 LOCATION

Ramachandrapuram mandal of Chittoor district, Andhra Pradesh lies between 13° 27' and 13° 31' N latitude and 79° 33' and 79° 37' E longitude (Fig.1).

4.2 CLIMATE

The study area was confined to semi-arid monsoonic climate with distinct summer, winter and rainy seasons. The mean annual atmospheric temperature was 28.04°C and mean annual rainfall was 1205.96 mm (Table 1). The meteorological data were also depicted in ombrothermic diagram (Fig.2).

4.3 PARENT MATERIAL

Pedons 1 and 3 occurring on plain lands, pedons 4 and 5 on very gentle slope and pedons 6 and 7 on gentle slope were developed from granite-gneiss. However, pedon 2 occurring on plains originated from alluvium.

4.4 TOPOGRAPHY

The topography of Ramachandrapuram mandal varied from plain (0-1%) to gently sloping (3-8%) with nil to moderate erosion.

Pedons 1, 2 and 3 were present on lower pediplain with nearly levelled slope (0-1%) whereas pedons 4 and 5 with very gentle slope (1-3%) and pedons 6 and 7 with gentle slope (3-8%) were distributed in upper pediplain.

4.5 LAND USE AND VEGETATION

The pedons studied were selected from the cultivated fields. The major crops grown were sugarcane, groundnut, paddy, redgram, sorghum, mango and coconut. The natural vegetation of the study area was *Parthenium hysterophorus*, *Lantana camara*, *Acalypha indica*, *Lucas aspera*, *Tectona grandis*, *Cyprus rotundus* and *Cynadon dactylon* (Table 2).

4.6 MORPHOLOGY OF TYPIFYING PEDONS

The detailed morphological and pedological features were depicted in Appendix - A. The summary of morphological features were presented in Table 4 and depicted in the Fig.3, 4 and 5.

4.6.1 Depth of pedons

The depth of different pedons studied was varying from 0.60 to more than 2.00 m and found to have moderately deep to very deep solum. Pedons 1, 2, 4, 5, 6 and 7 extended upto 1.57, 1.83, 1.65, 1.61, 0.60 and 0.91 m, respectively. However, pedon 3 was extended beyond 2.00 m. The pedons 6 and 7 were ended in weathered gneiss.

4.6.2 Number of horizons

Based on different morphological features, pedons 1 and 7 were differentiated into 4 horizons while pedons 2 and 3 were distinguished into 6 horizons. The pedons 4, 5 and 6 showed 5, 7 and 3 horizons, respectively.

4.6.3 Horizons and horizon sequence

The pedons studied were characterised by AC, AB and AEB profiles. The A horizon was designated as Ap by taking change in colour and structure due to cultivation into consideration in all the profiles. Based on the macromorphological features, the A horizon of pedons 5, 6 and 7 was vertically sub-divided into different sub-horizons. Pedons 1 and 3 exhibited AB horizon. The

B horizon is distinguished into Bw1, Bw2, Bw3, Bw4 and Bw5 in pedon 3 and Bt1, Bt2 and Bt3 in pedon 4. The C horizon was differentiated into C1, C2 and C3 in pedon 2. An eluvial E horizon was observed in pedon 4.

4.6.4 Horizon thickness

The thickness of the Ap horizon ranged from 0.10 to 0.23 m and the thickness of the sub-surface horizons was found to be between 0.10 to 0.91 m.

4.6.5 Horizon boundaries

All the pedons except pedon 1 exhibited clear smooth boundary in top layers whereas pedon 1 showed diffuse wavy boundary. The pedons 5, 6 and 7 exhibited clear smooth boundary throughout the profile. The pedons 1, 2, 3 and 4 showed diffuse wavy boundary in the sub-surface horizons.

4.6.6 Colour

Pedons 1, 2, 3 and 7 exhibited yellowish brown to very dark grayish brown colour with a hue of 7.5 YR to 10 YR, value in between 2 and 6 and chroma in the range of 1 to 6. In pedon 4 the

colour varied from dark red to dark brown with a hue varied from 2.5 YR to 10 YR, value of 3 to 5 and chroma of 2 to 6. Pedon 5 exhibited yellowish red to light yellowish brown colour with a hue varied from 5 YR to 10 YR, value of 3 to 6 and chroma in between 3 and 6. In case of pedon 6 the colour varied from dark red to yellowish brown with a hue in the range of 2.5 YR to 10 YR, value ranged from 3 to 5 and chroma between 4 and 6. The Munsell colour notation of hue, value and chroma were more or less similar in both moist and dry conditions.

4.6.7 Structure

With regard to type of soil structure, all the horizons in the pedons 4, 6 and 7 and most of the horizons in the remaining pedons exhibited sub-angular blocky. However, Ap and A2 horizons of pedon 5 and Bw2 horizon of pedon 1 showed angular blocky structure, C1 horizon in pedon 2 and Ap horizon of pedon 3 exhibited crumb structure and C2 and C3 horizons of pedon 2 had shown single grain structure.

The size or class of structural units varied from fine to coarse while grade or strength was 0 to 3 *i.e.* structureless to strong.

4.6.8 Texture

The texture of surface horizons varied from sandy clay loam to clay loam whereas in sub-surface horizons it varied from sandy to clay loam.

4.6.9 Consistence

The consistence varied from soft to very hard, loose to very firm and non-sticky and non-plastic to very sticky and very plastic in dry, moist and wet conditions, respectively in different horizons of all these studied pedons.

4.6.10 Cracks

Cracks of 3 to 5 mm wide to a depth of 35 cm were noticed only in pedon 1.

4.6.11 Slickensides

Indistinct and weak slickensides were observed below 0.60 m in the pedon 1 alone.

4.6.12 Porosity

The pores were fine to coarse in size and few to common in quantity in different layers of the pedons.

4.6.13 Roots

The roots in the pedons were fine to medium in size and few to common in quantity. The roots were almost absent below 1.00 m depth in all the pedons.

4.7 IMPORTANT MORPHOLOGICAL CHARACTERS OF THE TYPIFYING PEDONS

4.7.1 *Pedon 1*

This pedon was extended to a depth of 1.57 m and had four distinct horizons *viz.*, Ap, Bw1, Bw2 and Bw3. The pedon was dark yellowish brown to very dark grayish brown in colour. The texture varied from sandy clay loam to clay loam. Surface horizon and last horizon had medium, moderate and sub-angular blocky structure while sub-surface horizons had fine to medium, weak and sub-angular blocky structure. The consistence of the pedon was slightly hard to hard, firm to very firm and slightly sticky and slightly plastic in dry, moist and wet conditions, respectively. Strong effervescence was observed in the last horizon. Few and fine pores were observed in all the horizons. Few and medium sized roots were noticed in the surface horizon. All the horizons except the last horizon showed diffuse and wavy boundary. Clear

and smooth boundary was noticed in the last horizon. 3 to 5 mm wide cracks were seen in the upper horizons. Weak and indistinct slickensides were noticed in the sub-surface horizons (**Plate 1**).

4.7.2 Pedon 2

This solum was very deep extending upto a depth of 1.83 m with six distinct horizons *viz.*, Ap, A1, A2, C1, C2 and C3. The pedon had light brown to very dark grayish brown colour and showed sandy to sandy clay loam texture. The A horizons showed medium, moderate, sub-angular blocky structure and the C horizons exhibited coarse, structureless to weak and single grain to crumb structure. The consistence of the A horizons is slightly hard, friable and slightly sticky and slightly plastic whereas the C horizons exhibited loose, loose to very friable and non-sticky and non-plastic consistence in dry, moist and wet conditions, respectively. Last two horizons showed common and coarse pores and the remaining horizons exhibited few and fine pores. Few and fine roots were noticed only in the surface horizon. The surface horizon exhibited clear and smooth boundary. The sub-surface horizons showed clear to diffuse and smooth to wavy boundary (**Plate 2**).

4.7.3 Pedon 3

This pedon was very deep extending upto 2.08 m with six horizons *viz.*, Ap, Bw1, Bw2, Bw3, Bw4 and Bw5. The pedon was light brown to strong brown in colour with silty loam to clay loam texture. The surface horizon had fine, weak and crumb structure. The sub-surface horizons except the last horizon exhibited medium, moderate and sub-angular blocky structure whereas the last horizon had medium, strong and sub-angular blocky structure. The pedon exhibited soft to hard consistence in dry condition, very friable to firm consistence in moist condition and non-sticky and non-plastic to slightly sticky and slightly plastic consistence in wet condition. The pedons showed few to common and medium pores. Common and fine roots were observed in the surface horizon alone. The surface horizon showed clear and smooth boundary. The boundaries in the sub-surface horizons varied from clear to diffuse in distinctness and smooth to wavy in topography **(Plate 3)**.

4.7.4 Pedon 4

This was a very deep profile having five distinct horizons *viz.*, Ap, E, Bt1, Bt2 and Bt3. This pedon had dark red to dark brown colour with sandy loam to clay loam texture. The structure of the pedon varied from fine to coarse, weak to strong and sub-angular blocky. The consistence of the pedon was slightly hard to hard, friable to firm and non-sticky and non-plastic to slightly sticky and slightly plastic. Few and fine pores and roots were observed only in the surface horizon. Clear and smooth boundary was observed upto a depth of 1.0 m whereas diffuse and wavy boundary was noticed beyond 1.0 m depth of the profile **(Plate 4)**.

4.7.5 Pedon 5

This pedon was also one of the very deep profiles extending upto 1.61 m with seven horizons (Ap, A1, A2, A3, A4, A5 and A6) which had yellowish red to dark brown colour and sandy loam to clay loam texture. The pedon had shown fine to medium, weak to moderate, sub-angular blocky to angular blocky structure. The consistence of the pedon was loose to hard, friable to firm and non-sticky and non-plastic in dry, moist and wet conditions, respectively. In the surface horizon few and fine roots were observed. All the horizons in this pedon exhibited clear and smooth boundary **(Plate 5)**.

4.7.6 Pedon 6

This pedon was slightly deep with three horizons *viz.*, Ap, A1 and A2 and extended upto 0.60 m depth. This pedon had dark red to yellowish brown colour with sandy clay loam texture. The structure of the surface horizon was fine, weak, sub-angular blocky and that of the sub-surface horizons was medium, moderate and sub-angular blocky. The consistence of the pedon varied from hard to very hard when dry, friable to firm when moist and slightly sticky and slightly plastic when wet. All the horizons in the pedons exhibited clear and smooth boundary **(Plate 6)**.

4.7.7 Pedon 7

This solum was deep extending upto a depth of 0.91 m. The pedon showed four horizons *viz.*, Ap, A1 , A2 and A3, brown to very dark grayish brown in colour and sandy clay loam in texture. This pedon exhibited fine to medium, moderate and sub-angular blocky structure. Further, the consistence varied from slightly hard to hard (dry), friable to firm (moist) and slightly sticky and slightly plastic (wet). Few and fine pores and roots were noticed in the surface horizon. All the horizons in the pedon exhibited clear and smooth boundary **(Plate 7)**.

4.8 PHYSICAL PROPERTIES OF SOILS

Physical characteristics of the soils *viz.*, particle size, bulk density, particle density, water holding capacity, pore space, volume expansion and loss on ignition were presented in Table 5, 6, 7 and 8 and depth functions were represented in Fig.6 and 7.

4.8.1 Particle size analysis

The results of particle size analysis were presented in Table 5 and 6 and depth functions were depicted in the Fig.6 and 7.

4.8.1.1 Clay (< 0.002 mm) fraction

The clay content ranged from 4.33 to 35.64 per cent. The highest amount of clay was observed in Bw3 horizon of pedon 1 while the lowest amount of clay was recorded in C2 horizon of pedon 2. Pedon 1 exhibited an increasing trend with depth whereas pedons 5 and 7 showed a decreasing trend with depth. Pedon 2 exhibited an irregular decrease in clay content with depth. However, no specific trend with depth was observed in pedons 3, 4 and 6. Maximum values of clay content were observed in pedon 1 and minimum values were noticed in pedon 2. The mean clay content in all these pedons varied from 15.93 (pedon 2) to 31.59 per cent (pedon 1).

4.8.1.2 Silt (0.002 to 0.05 mm) fraction

Silt was in the range of 4.97 to 56.53 per cent. The pedon 3 recorded higher values ranging from 48.64 to 56.53 per cent. The pedon 2 exhibited lower values ranging from 4.97 to 17.46 per cent. The mean silt values in individual pedons varied from 9.85 to 52.73 per cent. Further, pedons 2 and 6 showed a decreasing trend with depth. No particular trend was observed in the remaining pedons.

4.8.1.3 Sand (0.05 to 2.00 mm) fraction

The results of particle size distribution revealed that the sand content in the pedons varied from 16.81 to 89.82 per cent. The sand content increased with depth in pedons 2, 5 and 6 while pedons 1 and 4 showed a decreasing trend with depth. However, pedons 3 and 7 did not show any particular depth function. Among the seven pedons, pedon 2 recorded relatively higher sand content ranging from 54.38 to 89.82 per cent whereas pedon 3 had lower sand content ranging from 16.81 to 24.59 per cent. The data on mean sand content of each pedon indicated that the mean sand content ranged from 20.89 to 74.22 per cent of the soil.

4.8.1.4 Ratios of different soil fractions

4.8.1.4.1 Sand / silt ratio

The values of sand / silt ratio ranged from 0.31 to 18.07. The higher values of 3.11 to 18.07 were registered in pedon 2. Pedon 3 recorded lower values ranging from 0.31 to 0.48. Pedons 1 and 4 followed a decreasing trend while pedons 2 and 6 showed an increasing trend with depth. In pedon 7, the values increased from Ap horizon to A1 horizon and later on decreased. However, pedons 3 and 5 did not show any specific trend with depth.

4.8.1.4.2 Silt / clay ratio

The silt/ clay ratio varied from 0.34 to 2.38. The lower values of 0.53 to 0.91 were observed in pedon 7. The higher values of 1.73 to 2.38 were noticed in pedon 3. All the pedons exhibited an irregular trend with depth.

4.8.1.4.3 Sand / silt + clay ratio

The ratio was found to be in between 0.20 and 8.82. The lowest values ranging from 0.20 to 0.33 were recorded in pedon 3 and the highest values of 1.19 to 8.82 were observed in pedon 2. Pedons 1 and 4 showed a decreasing trend and pedons 2, 5 and 6 exhibited an increasing trend with depth. However, pedons 3 and 7 did not show any specific trend with depth.

4.8.2 Physical constants

The results of physical constants were presented in Table 7 and 8.

4.8.2.1 Bulk density

Bulk density values of different layers in these seven pedons varied from 1.45 to 1.66 Mg m⁻³. The highest value (1.66 Mg m⁻³) was recorded in Bw3 horizon of pedon 1 whereas Ap horizon of pedon 3 exhibited the lowest value (1.45 Mg m⁻³). All the pedons exhibited an increasing trend with depth. The mean bulk density values in individual pedons ranged from 1.52 to 1.58 Mg m⁻³. The variation in bulk density among the different layers was 0.21 units.

4.8.2.2 Particle density

Particle density of different pedons ranged from 2.39 to 2.65 Mg m⁻³. Among all the pedons, pedon 2 exhibited relatively higher values ranging from 2.51 to 2.65 Mg m⁻³ whereas pedon 7 showed lower values ranging from 2.39 to 2.59 Mg m⁻³. All the pedons did not show any specific trend with depth. The mean particle density values in individual pedons ranged from 2.49 to 2.57 Mg m⁻³. The variation in particle density among the different layers was 0.26 units.

4.8.2.3 Water holding capacity

The values of water holding capacity varied from 19.96 to 47.81 per cent. Pedon 1 exhibited relatively higher values ranging from 38.15 to 47.81 per cent whereas pedon 2 had shown lower values ranging from 19.96 to 39.41 per cent. Pedon 1 showed an increasing trend whereas pedon 7 exhibited a decreasing trend with depth. The remaining pedons expressed an irregular trend with depth.

4.8.2.4 Pore space

The pedons were ranged between 20.51 to 57.98 per cent in pore space. Pedons 1 and 3 showed an increasing trend while pedons 2, 5 and 7 exhibited a decreasing trend with depth. However, pedons 4 and 6 exhibited an irregular trend with depth.

4.8.2.5 Volume expansion

The per cent volume expansion varied from 2.91 to 26.32. Pedon 7 recorded the higher values ranging from 17.24 to 26.32 per cent. The lower values ranging from 2.91 to 18.24 per cent were observed in pedon 1. Pedon 2 showed an irregular decrease in values with depth. Further, pedon 1 showed an increasing

trend with depth while pedons 5 and 7 exhibited a decreasing trend with depth. The remaining pedons 3, 4 and 6 did not show any particular trend with depth.

4.8.2.6 WHC / clay

Water holding capacity to clay ratio varied from 1.32 to 4.61. The highest value of 4.61 was noticed in C2 horizon of pedon 2 and the lowest value of 1.32 was observed in A1 horizon of pedon 2.

4.8.2.7 Loss on ignition

These values varied from 2.10 to 6.85 per cent. The highest value of 6.85 per cent observed in Bw3 horizon of pedon 1 and the lowest value of 2.10 per cent was noticed in C2 horizon of pedon 2.

4.9 PHYSICO-CHEMICAL PROPERTIES

The results of physico-chemical properties were depicted in Table 9 and 10.

4.9.1 Soil reaction

All the pedons studied were slightly acidic to moderately alkaline in reaction. The pH values of 1:2.5 soil water suspension ranged between 6.79 and 8.26. Pedon 6 exhibited an increasing trend while the remaining pedons did not show any particular trend with depth.

The pH values of 1:2.5 soil 1N KCl suspension ranged from 5.41 to 7.26. The lowest value of 5.41 was observed in Ap horizon of pedon 3 and the highest value of 7.26 was registered in A2 horizon of pedon 5.

4.9.2 Electrical conductivity

The electrical conductivity in saturation extract of different horizons of pedons ranged from 0.01 to 0.18 dSm⁻¹. The highest value of 0.18 dSm⁻¹ was registered in Bw3 horizon of pedon 1 and the lowest value of 0.01 dSm⁻¹ was noticed in Ap horizons of pedons 2 and 6. Pedons 1, 2, 6 and 7 had shown an increasing trend while pedon 4 exhibited an irregular trend with depth. However, pedons 3 and 5 had not shown any particular trend with depth.

4.9.3 Organic carbon

Organic carbon of the pedons ranged from 0.12 to 0.77 per cent. The lowest value of 0.12 per cent was noticed in C3 horizon of pedon 2 and the highest value of 0.77 per cent was observed in Ap horizon of pedon 6. Pedons 1, 2, 3, 6 and 7 had shown a decreasing trend with depth, whereas pedons 4 and 5 exhibited an irregular trend with depth.

4.9.4 Total nitrogen

The total nitrogen content ranged from 0.010 to 0.077 per cent. Higher values of 0.046 to 0.077 were noticed in pedon 6 while lower values of 0.010 to 0.056 were observed in pedon 2. Pedons 3 and 4 exhibited an irregular decrease with depth whereas the remaining pedons (1, 2, 5, 6, and 7) showed a decreasing trend with depth.

4.9.5 C/N ratio

The C/N ratio varied from 6.80 to 12.00. The highest ratio of 12.00 was noticed in C3 horizon of pedon 2 and the lowest ratio of 6.80 was observed in C1 horizon of pedon 2. Pedon 1 exhibited an increasing trend with depth whereas pedon 6 had shown a

decreasing trend with depth. However, the remaining pedons did not show any particular trend with depth.

4.9.6 Calcium Carbonate

The CaCO_3 content ranged from 0.45 to 1.83 per cent. Higher values ranging from 0.85 to 1.83 per cent were registered in pedon 1 while lower values ranging from 0.45 to 1.38 were noticed in pedon 2. However, CaCO_3 content was not found in all the horizons of pedon 6 and Bt1 and Bt3 horizons of pedon 4. Pedons 2, 4 and 5 had shown a decreasing trend with depth while pedon 7 exhibited an increasing trend with depth. Further, pedons 1 and 3 did not show any particular trend with depth.

4.10 ELECTRO-CHEMICAL PROPERTIES

The results of electro-chemical properties were presented in Table 11 and 12 and depicted in Fig.8 and 9.

4.10.1 Cation exchange capacity

The CEC values varied from 6.65 to 27.60 $\text{cmol(p+)}\text{kg}^{-1}$ soil. The highest value of 27.60 $\text{cmol(p+)}\text{kg}^{-1}$ soil was noticed in the Bw2 horizon of pedon 3 and the lowest value of 6.65 $\text{cmol(p+)}\text{kg}^{-1}$

soil was registered in A6 horizon of pedon 5. Further, the data on mean values revealed that the mean CEC values were ranged from 15.45 to 25.20 cmol(p+) kg^{-1} soil. Pedons 1 and 6 had shown an increasing trend with depth while pedons 2 and 7 exhibited a decreasing trend with depth. Pedons 4 and 5 had shown an irregular increase and decrease with depth, respectively. However, pedon 3 had not shown any particular trend with depth.

4.10.2 Exchangeable bases

The exchangeable bases in all the pedons were in the order of $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^{+} > \text{K}^{+}$ on the exchange complex.

4.10.3 Calcium

The exchangeable calcium was found to be the dominant cation on the exchange complex and the values varied from 2.00 to 17.60 cmol(p+) kg^{-1} soil. The lowest value of 2.00 cmol(p+) kg^{-1} soil was observed in A6 horizon of pedon 5 while the highest value of 17.60 cmol(p+) kg^{-1} soil was registered in Bw3 horizon of pedon 1. The per cent saturation of calcium varied from 26.29 to 64.16 on the exchange complex (Table 13). Further, the per cent saturation of calcium had shown an irregular decrease with depth in

pedons 2, 5 and 7 while an irregular increase with depth was noticed in pedon 1. However, no particular trend was observed in pedons 3, 4 and 6.

4.10.4 Magnesium

Next to calcium, magnesium was the dominant cation on the exchange complex. Magnesium contributed 21.87 to 33.80 per cent on the exchange complex. Magnesium content was ranged from 2.00 to 8.67 $\text{cmol(p+)}\text{kg}^{-1}$ soil. The highest value of 8.67 $\text{cmol(p+)}\text{kg}^{-1}$ soil was noticed in Bw1 horizon of pedon 1 while the lowest value of 2.00 $\text{cmol(p+)}\text{kg}^{-1}$ soil was registered in C2 and C3 horizons of pedon 2 and A6 horizon of pedon 5. Pedons 2 and 7 exhibited more or less a decreasing trend with depth while pedon 6 showed an increasing trend with depth. However, the remaining pedons (1, 3, 4 and 5) did not show any particular trend with depth.

4.10.5 Sodium

The exchangeable sodium content on the exchange complex varied from 0.93 to 2.43 $\text{cmol(p+)}\text{kg}^{-1}$ soil. The highest value of 2.43 $\text{cmol(p+)}\text{kg}^{-1}$ soil was noticed in Bt2 horizon of pedon 4 while

the lowest value of $0.93 \text{ cmol(p+)}\text{kg}^{-1}$ soil was recorded in A4 horizon of pedon 5. Pedon 1 showed an increasing trend with depth while pedons 5 and 6 exhibited a decreasing trend with depth. An irregular decrease with depth was observed in pedon 2 while an irregular increase with depth was noticed in pedon 4. However, pedons 3 and 7 did not show any particular trend with depth. The sodium was adsorbed to an extent of 16.79 per cent on the exchange complex.

4.10.6 Potassium

The exchangeable potassium content of pedons ranged from 0.10 to $1.02 \text{ cmol(p+)}\text{kg}^{-1}$ soil. The highest value of $1.02 \text{ cmol(p+)}\text{kg}^{-1}$ soil was observed in Ap horizon of pedon 3 and Bt2 horizon of pedon 4 while the lowest value of $0.10 \text{ cmol(p+)}\text{kg}^{-1}$ soil was noticed in C3 horizon of pedon 2 and E horizon of pedon 4. Pedons 6 and 7 showed an irregular decrease with depth whereas the remaining pedons did not show any specific depth function. As high as 6.90 per cent saturation of K was analyzed in Ap horizon of pedon 3 and as low as 0.68 per cent in E horizon of pedon 4 was noticed.

4.10.7 Base saturation

The per cent base saturation on the exchange complex was between 60.13 and 98.29. The highest value of 98.29 was observed in Bt2 horizon of pedon 4 and the lowest value of 60.13 was noticed in C3 horizon of pedon 2. All the pedons had shown an irregular trend with depth.

4.10.8 Calcium / Magnesium ratio

These ratios varied from 1.00 to 2.93. The highest ratio of 2.93 was noticed in Bw3 horizon of pedon 1 and the lowest ratio of 1.00 was registered in A6 horizon of pedon 5. Pedons 2, 5 and 7 had shown an irregular decrease with depth whereas the remaining pedons did not exhibit any specific depth function.

4.11 CHEMICAL COMPOSITION OF SOILS

The results of chemical composition in the horizon samples of pedons estimated by acid extract method were presented in Table 14 and 15 and depth functions were depicted in Fig. 10 and 11.

4.11.1 Silica (SiO_2)

The values of total silica content varied from 78.20 to 91.10 per cent. The highest value of 91.10 per cent was registered in C3 horizon of pedon 2 while the lowest value of 78.2 per cent was recorded in Bw1 and Bw5 horizons of pedon 3. Pedon 4 exhibited a decreasing trend with depth whereas pedon 3 showed an irregular trend with depth. However, the remaining pedons showed an increasing trend with depth.

4.11.2 Sesquioxides (R_2O_3)

The values of sesquioxides varied from 5.25 to 16.25 per cent. The highest value of 16.25 per cent was observed in Bt3 horizon of pedon 4 and the lowest value of 5.25 per cent was noticed in C3 horizon of pedon 2. Pedons 3 and 5 exhibited more or less an increasing trend with depth. Pedon 2 showed a decreasing trend with depth while in pedon 4 an increasing trend with depth was noticed. Further, pedons 1, 6 and 7 did not show any specific depth function.

4.11.3 Aluminum oxide (Al_2O_3)

The alumina content of the pedons was in between 4.29 and 12.29 per cent with a variation of 8.00 units. The highest value of 12.29 per cent aluminum oxide was obtained in Bt2 horizon of pedon 4. The lowest value of 4.29 per cent was registered in C1 horizon of pedon 2. In pedons 2, 5 and 7, alumina content was more or less decreased with depth while pedons 1 and 3 showed an increase upto 1 metre depth and afterwards exhibited a decreasing trend with depth. Pedon 4 had shown more or less an increasing trend with depth and pedon 6 did not show any specific depth function.

4.11.4 Iron oxide (Fe_2O_3)

The iron oxide content in the pedons was ranged from 0.39 to 4.53 per cent. The highest iron oxide content of 4.53 per cent was recorded in Bt3 horizon of pedon 4 and the lowest value of 0.39 per cent was noticed in case of C2 horizon of pedon 2. In pedons 2 and 7, iron oxide content was more or less decreased with depth while pedon 4 showed an irregular increasing trend with depth. However, the remaining pedons did not show any specific trend with depth.

4.11.5 Phosphorus pentoxide (P_2O_5)

The P_2O_5 content of the pedons was ranged from 0.02 to 0.11 per cent. The highest P_2O_5 content of 0.11 per cent was recorded in Ap horizons of pedons 1 and 5 while the lowest P_2O_5 content of 0.02 per cent was noticed in case of C horizons of pedon 2. Pedons 4 and 5 did not show any specific depth function while the remaining pedons showed a decreasing trend with depth.

4.11.6 Potassium oxide (K_2O)

These values ranged from 0.12 to 0.54 per cent. Relatively lower values of 0.12 to 0.39 per cent were noticed in pedon 2 whereas higher values of 0.39 to 0.54 per cent were recorded in pedon 7. The pedons 2 and 5 exhibited an irregular decrease with depth. Pedon 3 showed a decreasing trend with depth while pedon 4 exhibited an irregular increase with depth. However, the remaining pedons (1, 4, 6 and 7) did not show any particular trend with depth.

4.11.7 Sodium oxide (Na_2O)

The Na_2O content ranged from 0.06 to 0.17 per cent. The higher values of 0.12 to 0.17 per cent were noticed in pedon 1

whereas the lower values of 0.06 to 0.12 were recorded in pedon 2. Pedon 6 exhibited an increasing trend with depth while pedon 2 showed an irregular decrease with depth. The remaining pedons did not show any specific depth function.

4.11.8 Calcium oxide (CaO)

These values ranged from 0.86 to 2.98 per cent. Relatively higher values of 2.63 to 2.98 per cent were noticed in pedon 1 whereas lower values of 0.86 to 2.28 were recorded in pedon 2. Pedons 2, 3, 4 and 6 exhibited a decreasing trend with depth while pedons 1, 5 and 7 did not show any specific trend with depth.

4.11.9 Magnesium oxide (MgO)

The magnesium oxide content varied from 0.50 to 1.49 per cent. The highest value of 1.49 per cent was recorded in Ap horizon of pedon 1 whereas the lowest value of 0.50 per cent was noticed in C2 and C3 horizons of pedon 2. Pedons 2, 4, 6 and 7 showed a decreasing trend with depth while pedon 5 exhibited an irregular decrease with depth. Further, the pedons 1 and 3 did not show any specific depth function.

4.12 MOLAR CONCENTRATIONS AND MOLAR RATIOS

The values of molar concentrations and molar ratios were presented in Table 16 and 17.

4.12.1 Molar concentrations

The molar concentrations of SiO_2 ranged from 1.29 to 1.52 in between the horizons of all the pedons while R_2O_3 ($\text{Fe}_2\text{O}_3 + \text{Al}_2\text{O}_3$) contents ranged from 0.052 to 0.142.

4.12.2 Molar ratios

4.12.2.1 Silica / sesquioxide ratio ($\text{SiO}_2 / \text{R}_2\text{O}_3$)

The silica / sesquioxide values were varying from 9.15 to 30.40. The highest value (30.40) was observed in C3 horizon of pedon 2 while the lowest value (9.15) was exhibited by Bt3 horizon of pedon 4. An irregular increasing trend was noticed in pedons 2 and 5 and an irregular decreasing trend was observed in pedon 3. Further, an increasing trend was exhibited by pedon 7 while pedon 1 showed a decreasing trend. Pedon 6 did not show any particular trend with change in depth.

4.12.2.2 Silica / Alumina oxide ratio ($\text{SiO}_2 / \text{Al}_2\text{O}_3$)

These ratios varied from 10.40 to 35.23. The highest value 35.23 was observed in C1 horizon of pedon 2 whereas the lowest value of 10.40 was noticed in Bt3 horizon of pedon 4. Silica / Alumina oxide ratios were more or less decreased with depth in pedons 1 and 4 while the remaining pedons had shown an irregular trend with depth.

4.12.2.3 Silica / Iron oxide ratio ($\text{SiO}_2 / \text{Fe}_2\text{O}_3$)

The silica / iron oxide ratio ranged from 46.42 to 750.00. The highest value of 750.00 was recorded in C2 horizon of pedon 2 while the lowest value of 46.42 was noticed in Bt3 horizon of pedon 4. A decreasing trend was observed in pedon 4 while the remaining pedons showed an irregular trend with depth.

4.12.2.4 Alumina / Iron oxide ratio ($\text{Al}_2\text{O}_3 / \text{Fe}_2\text{O}_3$)

The ratios ($\text{Al}_2\text{O}_3 / \text{Fe}_2\text{O}_3$) were ranging from 2.35 to 11.28. The lowest value of 2.35 was exhibited by C3 horizon of pedon 2 whereas the highest value of 11.28 was recorded in A6 horizon of

pedon 5. A decreasing trend with depth was observed in pedon 2 while the remaining pedons showed an irregular trend with depth.

4.13 NUTRIENT STATUS

The results of the total macro and micronutrients in horizon samples were presented in Table 18, 19, 20 and 21 and depth functions were depicted in Fig.12, 13, 14 and 15.

4.13.1 Macronutrients

Results of macronutrients were presented in the Table 18 and 19 and depicted in Fig.12 and 13.

4.13.1.1 *Total nitrogen*

The total nitrogen content ranged from 98.00 to 770.00 mg kg⁻¹ soil. The lowest value (98.00 mg kg⁻¹ soil) was observed in C3 horizon of pedon 2. All the pedons except pedons 3 and 4 exhibited a decreasing trend with depth. Pedons 3 and 4 showed an irregular decrease with depth. The mean values of the total nitrogen varied from 282.33 to 573.34 mg kg⁻¹ soil.

4.13.1.2 Total phosphorus

The total phosphorus content varied from 75.00 to 487.50 mg kg⁻¹ soil. The highest content (487.50 mgkg⁻¹ soil) was recorded in Ap horizon of pedon 5 and the lowest value (75.00 mg kg⁻¹ soil) was noticed in C3 horizons of pedon 2. All the pedons except pedons 4 and 5 showed a decreasing trend with depth whereas pedons 4 and 5 exhibited an irregular decrease with depth. Mean values for total phosphorus in these soils were ranging from 235.41 to 390.00 mg kg⁻¹ soil.

4.13.1.3 Total potassium

The total potassium content was found to be varied from 1000.00 to 4500.00 mg kg⁻¹ soil. The highest content (4500.00 mg kg⁻¹ soil) was registered in A1 horizon of pedon 7 and the lowest content (1000.00 mg kg⁻¹ soil) was noticed in C3 horizon of pedon 2. All the pedons did not show any definite pattern with change in depth. Mean values for total potassium in these soils were ranging from 2125.00 to 4000.00 mg kg⁻¹ soil.

4.13.1.4 Total sulphur

Total sulphur content in the horizons of different pedons ranged from 85.00 to 375.00 mg kg⁻¹ soil. The lowest value (85.00 mg kg⁻¹ soil) was recorded in C3 horizon of pedon 2 whereas the highest value, (375.00 mg kg⁻¹ soil) was registered in Ap horizon of pedon 5. Pedon 4 did not show any specific trend with depth while pedon 5 exhibited an irregular decrease with depth. However, the remaining pedons exhibited a decreasing trend with depth. Mean values for total sulphur in these soils were ranging from 209.16 to 293.33 mg kg⁻¹ soil.

4.13.2 Micronutrients

The micronutrients results were presented in Table 20 and 21 and depicted in Fig.14 and 15.

4.13.2.1 Total zinc

Total zinc was ranging from 9.50 to 30.50 mg kg⁻¹ soil. The highest content (30.50 mg kg⁻¹ soil) was noticed in Bw2 horizon of pedon 1. The lowest content (9.50 mg kg⁻¹ soil) was recorded in C3 horizon of pedon 2. Pedons 2 and 5 exhibited an irregular

decreasing trend with depth while pedon 4 showed a decreasing trend with increasing depth. However, the remaining pedons did not show any particular trend with depth. The mean values of total zinc were between 15.29 and 27.00 mg kg⁻¹ soil.

4.13.2.2 Total copper

The total copper content of the horizons of different pedons was varying from 16.25 to 34.00 mg kg⁻¹ soil. The highest content of 34.00 mg kg⁻¹ soil was registered in Bw3 horizon of pedon 1 while the lowest content of 16.25 mg kg⁻¹ soil was noticed in C3 horizon of pedon 2. Pedons 1, 4 and 7 showed an increasing trend with depth while pedons 2 and 5 exhibited an irregular decrease with depth. A decreasing trend with depth was observed in pedon 6. Further, pedon 3 did not show any particular trend with depth. The mean values of the total copper content varied from 19.38 to 31.25 mg kg⁻¹ soil.

4.13.2.3 Total iron

The total iron content ranged from 0.27 to 3.17 per cent. The highest content of 3.17 per cent was observed in Bt3 horizon of

pedon 4 and the lowest value of 0.27 per cent was recorded in C2 horizon of pedon 2. Pedon 4 exhibited an irregular increase with depth while pedon 2 showed an irregular decrease with depth. However, the remaining pedons exhibited an irregular trend with depth. The mean values of the total iron content varied from 1.04 to 2.30 per cent.

4.13.2.4 Total manganese

The total manganese content ranged from 176.00 to 620.00 mg kg⁻¹ soil. The highest content of total manganese (620.00 mg kg⁻¹ soil) was observed in Ap horizon of pedon 4 and the lowest value (176.00 mg kg⁻¹ soil) was recorded in C2 horizon of pedon 2. Pedons 2 and 3 showed an irregular decreasing trend with depth while the remaining pedons 1, 4, 5, 6 and 7 exhibited a decreasing trend with depth. The mean values of total manganese content varied from 259.83 to 547.40 mg kg⁻¹ soil.

4.14 pH, EC, ORGANIC CARBON AND NUTRIENT STATUS OF SURFACE SOIL SAMPLES

Means and ranges of pH, EC, organic carbon and available nutrients in surface soil samples collected from the different

revenue villages of Ramachandrapuram mandal (Appendix B) were presented in Table 22 and 23 and the fertility status of the mandal was shown in Fig.16 and 17.

4.14.1 pH (1:2.5)

Among the means of all revenue villages, the highest mean value of 8.10 was observed in Ramachandrapuram village in which pH ranged from 7.36 to 8.36. The lowest mean value of 6.97 was observed in Sanjeevarayapuram village wherein pH values varied from 6.43 to 7.38. The overall mean of all revenue villages was 7.62 with a range of 6.39 to 8.36 which indicates that the soils of this mandal were slightly acidic to alkaline in reaction.

4.14.2 Electrical conductivity

The highest mean value of 0.09 dSm⁻¹ was observed in Ramachandrapuram village in which EC values ranged from 0.09 to 0.11 dSm⁻¹. The lowest mean value of 0.02 dSm⁻¹ was observed in C.K.Palli and Nennuru villages with a range of 0.01 to 0.05 dSm⁻¹. The overall mean of all revenue villages was 0.06 dSm⁻¹ with a range of 0.01 to 0.12 dSm⁻¹ which indicates that the soils of the mandal were non-saline in nature.

4.14.3 Organic carbon

Among the means of all revenue villages, the highest mean value of 0.63 per cent was observed in Gangireddipalli village in which organic carbon content ranged from 0.55 to 0.71 per cent. The lowest mean value of 0.48 per cent was observed in Nethakuppam village samples wherein the organic carbon content varied from 0.42 to 0.59 per cent. The overall mean of all revenue villages of the mandal was 0.56 per cent with a range of 0.41 to 0.71 per cent, which confirmed that the soils in all the villages of Ramachandrapuram mandal were low in organic carbon status.

4.14.4 Available nitrogen

The highest mean value of 149.09 kg ha⁻¹ was noticed in Sorakayalapalem village in which nitrogen content ranged from 98.26 to 178.13 kg ha⁻¹. The lowest mean value of 82.96 kg ha⁻¹ was observed in C.Ramapuram village wherein the available nitrogen content varied from 54.93 to 102.26 kg ha⁻¹. The overall nutrient index (NI) for this mandal was 1.00 (Table 23) which indicated that the soils were low in available nitrogen. All the eighty samples were classified under low category with regard to available nitrogen status (Appendix B).

4.14.5 Available phosphorus

The mean available phosphorus content in different revenue villages of the mandal varied from 15.77 to 19.48 kg ha⁻¹. The highest mean available phosphorus of 19.48 kg ha⁻¹ was observed in Ramachandrapuram village in which P content varied from 15.28 to 23.96 kg ha⁻¹ soil. The lowest mean value of 15.77 kg ha⁻¹ soil was noticed in Nethakuppam village wherein the available P content ranged from 9.29 to 18.73 kg ha⁻¹. Overall nutrient index (NI) was 1.96 (Table 23) for the soils of mandal which indicated that the soils were medium in available phosphorus. However, the analytical data of surface soil samples revealed that about 3 samples were in low category and the remaining 77 samples were in medium category (Appendix B).

4.14.6 Available potassium

The highest mean value of 276.88 kg ha⁻¹ was observed in Ramachandrapuram village in which available potassium content ranged from 225.00 to 310.00 kg ha⁻¹. The lowest mean value of 200.00 kg ha⁻¹ was observed in Nethakuppam village samples wherein potassium content varied from 155.00 to 285.00 kg ha⁻¹. The overall mean of all the revenue villages was 237.34 kg ha⁻¹ soil

and ranged from 135.00 to 320.00 kg ha⁻¹ soil. The overall nutrient index (NI) of this mandal was 2.37 (Table 23) which indicated that the soils of the mandal were high in available K. However, the available K content was medium in 51 surface soil samples and high in 29 surface soil samples (Appendix B).

4.14.7 Available sulphur

The highest mean value of 6.81 mg kg⁻¹ soil was noticed in Nennuru village in which the available sulphur content ranged from 4.28 to 9.82 mg kg⁻¹ soil. The lowest mean value of 5.12 mg kg⁻¹ soil was observed in Ramachandrapuram village wherein the available sulphur content varied from 3.42 to 6.55 mg kg⁻¹ soil. The overall mean of all revenue villages was 6.21 mg kg⁻¹ soil which indicated that the soils of the mandal were deficient in available sulphur. Further, the available sulphur in all the eighty surface soil samples was found to be below the critical limit and the soils were found to be deficient in available sulphur (Appendix B).

4.14.8 Available micronutrients

Means and ranges of available micronutrients in surface soil samples collected from different revenue villages of the

Ramachandrapuram mandal were presented in Table 23 and micronutrient fertility status was depicted in Fig.16.

4.14.8.1 Available zinc

Among the means of all revenue villages the highest mean value of 0.75 mg kg⁻¹ soil was recorded in Anupalli village in which available zinc content ranged from 0.34 to 1.04 mg kg⁻¹ soil while the lowest mean value of 0.46 mg kg⁻¹ soil was noticed in Nethakuppam village, where in it ranged from 0.26 to 0.59 mg kg⁻¹ soil. The overall mean of all the revenue villages was 0.58 mg kg⁻¹ soil with a range of 0.21 to 1.04 mg kg⁻¹ soil, which indicated that the soils of the mandal were deficient in available zinc. However, about 32 surface soil samples were sufficient and 48 surface soil samples were deficient with respect to available zinc (Appendix B).

4.14.8.2 Available copper

The highest mean value of 0.89 mg kg⁻¹ soil was noticed in Ramachandrapuram village in which available copper content ranged from 0.64 to 1.21 mg kg⁻¹ soil. The lowest mean value of 0.47 mg kg⁻¹ soil was observed in Gangireddipalli village, wherein

the available copper content varied from 0.38 to 0.59 mg kg⁻¹ soil. The overall mean of all revenue villages was 0.70 mg kg⁻¹ soil with a range of 0.21 to 1.32 mg kg⁻¹ soil which indicates that the soils of the mandal were sufficient in available copper. All the surface soil samples analysed indicated that all the samples were sufficient with regard to available copper (Appendix B).

4.14.8.3 Available iron

Among the means of all revenue villages the highest mean of 4.04 mg kg⁻¹ soil was noticed in Ramachandrapuram village in which available iron content ranged from 2.49 to 5.82 mg kg⁻¹ soil whereas the lowest mean value of 2.28 mg kg⁻¹ soil was recorded in Sanjeevarayapuram village samples wherein it ranged from 1.09 to 3.13 mg kg⁻¹ soil. The overall mean of all revenue villages was 3.20 mg kg⁻¹ soil with a range of 1.09 to 5.82 mg kg⁻¹ soil which confirmed that the soils of the mandal were deficient in available iron content. The analyses of surface soil samples indicated that about 12 samples were above the critical limit and the remaining 68 samples were below the critical limit (Appendix B).

4.14.8.4 Available manganese

The highest mean of 9.94 mg kg⁻¹ soil was recorded in Gangireddipalli village in which the available manganese content ranged from 8.28 to 12.33 mg kg⁻¹ soil. The lowest mean value of 6.76 mg kg⁻¹ soil was noticed in Sanjeevarayapuram village with a range of 5.28 to 8.61 mg kg⁻¹ soil. The overall mean of all revenue villages was 8.28 mg kg⁻¹ which indicated that the soils were sufficient in available manganese content. All the surface soil samples were sufficient in available manganese.

4.15 MINERALOGY OF CLAY FRACTION

The X-ray diffraction analysis was carried out in the clay fraction (<2 micron) of soil samples collected from control section (25-100 cm depth) of the pedons. The d-spacings of different clay minerals observed in X-ray diffractograms were presented in Table 24 and the relative proportion of clay minerals was given in Table 25.

Mineralogical studies by X-ray diffractograms of soil clays were obtained with the following six treatments.

1. Ca-saturated at room temperature (25°C)
2. Ca-saturated and ethylene glycol solvated
3. K-saturated at room temperature (25°C)
4. K-saturated and heated at 110°C
5. K-saturated and heated at 300°C
6. K-saturated and heated at 550°C

Pedon 1

X-ray diffractograms of clay fraction for pedon 1 are presented in Fig.18.

1. Presence of smectite was identified by the following reflections.
 - a. Ca-saturated with ethylene glycol solvation: strong reflection at 1.721 nm d-spacing.
 - b. Ca-saturation at room temperature: A sharp peak at 1.430 nm d-spacing.
 - c. K-saturation at 25°C and 110°C: Conspicuous peaks at 1.235 and 1.002 nm d-spacings, respectively.
 - d. K-300°C and 550°C: Sharp well defined peaks at 1.002 and 0.995 nm d-spacings, respectively.

2. Feldspars were identified by the following reflections.
 - a. Ca-saturated with ethylene glycol solvation: Small peaks at 0.319 and 0.304 nm d-spacings.
 - b. Ca-saturation at room temperature: Small and sharp peaks at 0.325, 0.319 and 0.304 nm d-spacings.
 - c. K-saturation at 25°C: Small peaks at 0.404, 0.367, 0.325 and 0.320 nm d-spacings.
 - d. K-saturation at 110°C: Small peaks at 0.402, 0.325 and 0.320 nm d-spacings.
 - e. K-saturation at 300°C: Small peaks at 0.403, 0.325 and 0.320 nm d-spacings.
 - f. K-saturation at 550°C: A small peak at 0.318 nm d-spacing.

3. Kaolinite was identified by the following peaks at different d-spacings.
 - a. First order peaks at 0.711, 0.721, 0.721, 0.716 and 0.718 nm in Ca-saturated with ethylene glycol solvated, Ca-saturated at room temperature (25°C), K-25°C,

K-110°C and K-300°C treatments, respectively. However, no diffraction was observed in K-550°C treatment.

- b. Small and sharp second order peaks were identified at 0.357, 0.358, 0.355, 0.356 and 0.357 nm d-spacings in Ca-saturated ethylene glycol solvated, Ca-saturated at room temperature (25°C), K-25°C, K-110°C and K-300°C treatments, respectively. However, the peaks vanished when K-saturated sample was heated to 550 °C.

- 4. Presence of illite in the clay sample was identified by the following peaks with different treatments.

- a. Diffractions at 1.001, 0.993, 1.005, 1.002, 1.002 and 0.995 nm d-spacings were observed in Ca-saturated with ethylene glycol solvated, Ca-saturated at room temperature (25°C), K-25°C, K-110°C, K-300°C and K-550°C treatments, respectively.
- b. Sharp second order peaks were observed at 0.500, 0.499, 0.500, 0.501, 0.504 and 0.499 nm d-spacings in Ca-saturated with ethylene glycol solvated, Ca-25°C, K-25°C, K-110°C, K-300°C and K-550°C treatments, respectively.

- c. Sharp conspicuous third order peaks were observed at 0.334, 0.334, 0.335, 0.335, 0.335 and 0.333 nm d-spacings in Ca-saturated with ethylene glycol solvated, Ca-25°C, K-25°C, K-110°C, K-300°C and K-550°C treatments, respectively.
5. Presence of traces of quartz was identified by small peaks at 0.426, 0.426, 0.427, 0.426, 0.426 and 0.423 nm d-spacings in Ca-saturated with ethylene glycol solvation, Ca-25°C, K-25°C, K-110°C, K-300°C and K-550°C treatments, respectively.

Semi-quantitative estimates revealed that smectite (69.40%) was dominant clay mineral followed by feldspars (14.56%), kaolinite (9.24%) and illite (6.80%).

Pedon 2

The diffraction pattern (Fig.19) of clay sample of pedon 2 had shown an intensive large peak at 1.649 nm d-spacing on ethylene glycol solvation and a sharp peak at 1.473 nm d-spacing in Ca-saturated sample at room temperature (25°C) indicated the presence of smectite. Further, a peak at 0.999 nm d-spacing in

K-saturated sample at room temperature (25°C) followed by peaks at 0.999, 1.000 and 1.000 nm d-spacings in K-saturated and heated to 110°C, 300°C and 550°C treatments, respectively confirmed the presence of smectite.

Illite had shown small peaks at 1.000 and 1.002 nm d-spacings on ethylene glycol solvation and in Ca-saturated sample at room temperature (25°C), respectively. Illite also showed sharp peaks at 0.999, 0.999, 1.000 and 1.000 nm d-spacings in K-saturated and heated to 25°C, 110°C, 300°C and 550°C treatments, respectively. Second order peaks at 0.493 and 0.499 nm d-spacings in ethylene glycol solvation and Ca-saturated sample at room temperature and small peak at 0.500 nm d-spacings in K-saturated sample at room temperature (25°C) and similar peaks in all other treatments were observed. Third order peaks at 0.334, 0.334, 0.332, 0.332, 0.335 and 0.333 nm d-spacings were observed in Ca-saturated with ethylene glycol solvated, Ca-saturated at room temperature (25°C), K-25°C, K-110°C, K-300°C and K-550°C treatments, respectively confirmed the presence of illite.

A small peak at 0.728 nm d-spacing followed by a higher order peak at 0.336 nm d-spacing in Ca-saturated ethylene glycol solvated sample and persistence of similar peaks on Ca-saturated at room temperature (25°C), K-saturation and heating up to 300°C (*i.e.* 25°C, 110°C and 300°C), but their disappearance on K-550°C heated treatment, confirmed the presence of kaolinite.

Presence of small peaks at 0.319 and 0.304 nm d-spacings in Ca-saturated with ethylene glycol solvated sample and presence of similar peaks in all the remaining treatments indicated the presence of feldspars.

Semi quantitative estimates of clay minerals based on relative areas under corresponding peaks revealed that smectite was the dominant mineral (59.07%) followed by illite (20.64%), kaolinite (18.51%) and feldspars (1.78%).

Pedon 3

X-ray diffractograms are presented in Fig.20.

1. A significant quantity of feldspars was identified by their small peaks at 0.325 and 0.319 nm d-spacings in Ca-saturated with ethylene glycol solvation and small peaks at 0.641, 0.402, 0.324 and 0.319 nm d-spacings in Ca-saturated at room temperature and similar peaks were observed in K-25°C, K-110°C, K-300°C and K-550°C treatments.
2. Presence of illite in the clay fraction was identified by following peaks at different treatments.
 - a. First order peaks at 0.997 nm and 0.992 nm d-spacings were observed in Ca-saturated with ethylene glycol solvation treatments and Ca-saturated at room temperature treatments, respectively. Further, similar peaks were observed at 1.002, 0.996, 0.999 and 0.987 nm d-spacings in K-25°C, K-110°C, K-300°C and K-550°C treatments, respectively.

- b. Second order peaks were also observed at 0.502, 0.499, 0.499, 0.500, 0.500 and 0.499 nm d-spacings with Ca-saturated with ethylene glycol solvation, Ca-25°C, K-25°C, K-110°C, K-300°C and K-550°C treatments, respectively.
- c. Third order peak at 0.334 nm d-spacing was noticed in Ca-saturated with ethylene glycol solvated treatment and similar peaks were observed in all other treatments.

All the above characteristic peaks indicated the presence of illite.

- 3. Kaolinite was identified by the following peaks at different d-spacings.
 - a. A strong first order peak at 0.727 nm d-spacing in Ca-saturated ethylene glycol solvated treatment and similar peaks in all other treatments (Ca-25°C, K-25°C, K-110°C and K-300°C) except in K-saturated and heated to 550°C treatment indicated the presence of kaolinite.
 - b. Small second order peaks at 0.355, 0.355, 0.355, 0.357 and 0.357 nm d-spacings were observed in Ca-saturated with ethylene glycol solvated, Ca-25°C, K-25°C, K-110°C

and K-300°C treatments, respectively. The peak is not found in K-550°C treatment which confirmed the presence of kaolinite.

Semi quantitative estimates had shown that feldspars (39.06%) were relatively more followed by illite (34.38%) and kaolinite (26.56%).

Pedon 4

The diffraction patterns of clay fraction were depicted in Fig.21. The X-ray diffractograms of clay exhibited an intense large peak at 0.727 nm d-spacing followed by a higher order peak at 0.358 nm d-spacing in Ca-saturated ethylene glycol solvation treatment indicated the presence of kaolinite. These peaks were persisted on Ca-saturation at room temperature and K-saturation at room temperature, 110°C and 300°C but collapsed in K-saturated and heated to 550°C treatment, confirmed the presence of kaolinite.

Presence of smectite was detected by a small peak at 1.494 nm d-spacing in Ca-saturated sample at room temperature and the peak was extended to 1.674 nm d-spacing on ethylene glycol solvation. Further, the peak was shifted to 1.001 nm d-spacing with K-saturation at room temperature, 0.998 nm d-spacing with K-saturation at 110°C, 1.001 nm d-spacing with K-saturation at 300°C and 0.992 nm d-spacing with K-saturation at 550°C.

A sharp large peak observed at 0.993 nm d-spacing followed by higher order peaks at 0.499 nm and 0.334 nm d-spacings in Ca-saturated with ethylene glycol solvation treatment and persistence of these peaks in all other treatments indicated the presence of illite clay mineral.

Feldspars were identified by small peaks at 0.325, 0.319 and 0.304 nm d-spacings in Ca-saturated ethylene glycol solvated treatment, 0.319 and 0.304 nm d-spacings in Ca-saturated at room temperature treatments. Small peaks at 0.402, 0.325 and 0.320 nm d-spacings at K-25°C treatment and similar peaks were observed in all other treatments *i.e.*, K-110°C, K-300°C and K-550°C treatments.

A very small peak observed at 0.424 nm d-spacing indicated the presence of small amount of quartz.

Semi-quantitative estimates had shown that kaolinite (41.29%) was the dominant clay mineral followed by smectite (32.99%), illite (20.33%), feldspars (3.11%) and quartz (2.28%).

Pedon 5

X-ray diffractograms of clay fraction for pedon 5 are presented in Fig.22.

1. Presence of smectite was identified by the following reflections.
 - a. Ca-saturated with ethylene glycol salvation: A strong peak at 1.638 nm d-spacing.
 - b. Ca-saturation at room temperature: A sharp peak at 1.529 nm d-spacing.
 - c. K-saturated at 25°C and 110°C: Conspicuous peaks at 1.324 and 1.005 nm d-spacings, respectively.
 - d. K-300°C and K-550°C: Sharp peaks at 1.891 and 0.983 nm d-spacings, respectively.

2. Kaolinite was identified by the following peaks at different d-spacings.
 - a. A strong first order peak at 0.724 nm d-spacing in Ca-saturated at room temperature and sharp peak at 0.726 nm d-spacing in Ca-saturated with ethylene glycol solvated sample and similar peaks in all other K-saturated treatments (K-25°C, K-110°C and K-300°C) except in K-saturated and heated to 550°C treatment indicated the presence of kaolinite.
 - b. Small second order peaks at 0.356 nm d-spacing in Ca-saturated with ethylene glycol solvated treatment, 0.357 nm d-spacing in Ca-saturated treatment and at 0.355 nm d-spacing in K-25°C, 0.356 nm d-spacing in K-110°C and 0.359 nm d-spacing in K-300°C treatments and disappearance of the similar peak in K-550°C treatment confirmed the presence of kaolinite.
3. Presence of illite in the clay fraction was identified by the following peaks at different treatments.
 - a. First order peaks at 1.008 and 1.006 nm d-spacings were observed in Ca-saturated with ethylene glycol solvation

and Ca-saturated at room temperature treatments, respectively. Further, similar peaks were observed at 0.997, 1.005, 1.004 and 0.983 nm d-spacings in K-25°C, K-110°C, K-300°C and K-550°C treatments, respectively.

b. Second order peaks were also observed at 0.500, 0.498, 0.501, 0.501 and 0.499 nm d-spacings with Ca-25°C, K-25°C, K-110°C, K-300°C and K-550°C treatments, respectively.

c. Third order peaks at 0.335 and 0.334 nm d-spacings were noticed in Ca-saturated with ethylene glycol solvated treatment and Ca-saturated at room temperature. Furthermore, the third order peaks were also observed at 0.334, 0.335, 0.335 and 0.334 nm d-spacings in K-25°C, K-110°C, K-300°C and K-550°C treatments, respectively.

All the above characteristic peaks indicted the presence of illite.

4. Feldspars were identified by the following peaks at different d-spacings.

a. Small peaks at 0.403, 0.324, 0.320 and 0.305 nm d-spacings in Ca-saturated with ethylene glycol solvation treatment.

- b. Small peaks at 0.320 and 0.305 nm d-spacings in Ca-saturated at room temperature.
- c. Small peaks at 0.400 and 0.319 nm d-spacings in K-saturated at room temperature.
- d. Small peaks at 0.319, 0.319 and 0.318 nm d-spacings in K-110°C, K-300°C and K-550°C treatments, respectively.

In this pedon smectite mineral was relatively dominant (39.87%) followed by kaolinite (26.90%), illite (24.05%) and feldspars (9.18%).

Pedon 6

The diffraction patterns of clay fraction were depicted in Fig.23.

The clay fraction showed the presence of kaolinite which was recognized by a large intense peak at 0.723 nm d-spacing with Ca-saturated ethylene glycol solvated treatment and 0.722 nm d-spacing with Ca-saturated at room temperature treatment. The peak persisted in the treatments such as K-25°C and K-saturated and heated to 110°C and 300°C but disappeared in K-saturated and heated to 550°C.

Sharp peaks at 1.002 nm (first order), 0.501 nm (second order) and 0.335 nm (third order) d-spacings in Ca-saturated ethylene glycol solvated treatment and persistence of these peaks in all other treatments indicted the presence of illite.

The clay fraction showed the presence of small quantities of feldspars which was recognized by a small peak at 0.319 nm d-spacing in Ca-saturated with ethylene glycol solvated sample and small peaks at 0.411 and 0.319 nm d-spacings in Ca-saturated at room temperature. Further, small peaks at 0.325 and 0.320 nm d-spacings in K-25°C treatment and similar peaks in K-110°C, K-300°C and K-550°C treatments also indicated the presence of feldspars.

Semi-quantitative estimates had shown that kaolinite (70.80%) was the dominant clay mineral followed by illite (23.74%) and feldspars (5.46%).

Pedon 7

The diffraction patterns of clay fraction were depicted in Fig.24.

The X-ray diffraction pattern of clay exhibited a small and weak peak at 0.996 nm d-spacing followed by higher order peaks at 0.499 nm d-spacing and 0.334 nm d-spacing in Ca-saturated ethylene glycol solvated treatment, which persisted in all other treatments. This indicated the presence of illite clay mineral.

An intense large peak at 0.716 nm d-spacing followed by a higher order peak at 0.355 nm d-spacing in Ca-saturated ethylene glycol solvated treatment indicated the presence of kaolinite. These peaks were persisted with Ca-saturated at room temperature, K-25°C, K-110°C and K-300°C. However, these peaks collapsed on K-saturation and heated to 550°C confirmed the presence of kaolinite.

Presence of smectite was detected by an intense large peak at 1.711 nm d-spacing in Ca-saturated with ethylene glycol solvated treatment and a peak at 1.415 nm d-spacing in Ca-saturated sample at room temperature. Further, the peak was shifted to 1.002 nm d-spacing with K-saturation at room temperature, 1.001 nm d-spacing with K-saturation at 300°C and 0.988 nm d-spacing with K-saturation at 550°C.

The presence of feldspars was identified by a small peak at 0.304 nm d-spacing in Ca-saturated with ethylene glycol solvated sample and small peaks at 0.319 and 0.304 nm d-spacings in Ca-saturated at room temperature. However, existence of small peaks at 0.403, 0.325 and 0.319 nm d-spacings in K-25°C treatment and similar peaks in K-110°C, K-300°C and K-550°C treatments also proved the presence of feldspars.

Semi-quantitative estimates had shown that illite (31.35%) was relatively dominant clay mineral followed by kaolinite (28.24%), smectite (26.68%) and feldspars (13.73%).

14.16 SOIL CLASSIFICATION

The detailed taxonomic classification of soil resources of Ramachandrapuram mandal was given in the Table 25. Based on the morphological characters (Table 4 and Appendix A) and physical, physico-chemical and chemical properties, the soils of Ramachandrapuram mandal were classified upto series level as per soil taxonomy (Soil Survey Staff, 1998).

4.17 LAND CAPABILITY CLASSIFICATION

The details of land capability classes and sub-classes assigned to the soils of Ramachandrapuram mandal were given in the Table 27. Land capability sub-classes were assigned for the soils based on the kind and severity of limitations *viz.*, erosion risk (e), wetness (w), rooting zone (soils) limitations (s) and climatic limitations (c). Based on these criteria the soils of Ramachandrapuram mandal have been classified into different capability sub-classes such as:

- IIs : Good cultivable lands (Pedons 1 and 3)
- IIIIs : Moderately good cultivable lands (Pedon 2)
- IIIes : Moderately good cultivable lands (Pedons 4 and 5)
- IVes : Fairly good cultivable lands (Pedons 6 and 7).

Table 16: Molar concentrations and molar ratios of the soils

Pedon No & Horizon	Depth (m)	Molar concentration				Molar ratio			
		SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	R ₂ O ₃	SiO ₂ / R ₂ O ₃	SiO ₂ / Al ₂ O ₃	SiO ₂ / Fe ₂ O ₃	Al ₂ O ₃ / Fe ₂ O ₃
Pedon 1									
Ap	0.00 – 0.23	1.39	0.013	0.070	0.083	16.74	19.86	106.92	5.38
Bw1	0.23 – 0.61	1.35	0.020	0.088	0.108	12.50	15.34	67.50	4.40
Bw2	0.61 – 1.08	1.33	0.019	0.100	0.119	11.18	13.30	70.00	5.26
Bw3	1.08 – 1.57+	1.33	0.018	0.096	0.114	11.66	13.85	73.90	5.33
Pedon 2									
Ap	0.00 – 0.20	1.40	0.014	0.073	0.087	16.09	19.18	100.00	5.21
A1	0.20 – 0.67	1.43	0.013	0.060	0.073	19.59	23.83	110.00	4.60
A2	0.67 – 0.92	1.46	0.011	0.050	0.061	23.93	29.20	132.73	4.55
C1	0.92 – 1.24	1.48	0.012	0.042	0.054	27.40	35.23	123.33	3.50
C2	1.24 – 1.55	1.50	0.002	0.053	0.055	27.27	28.30	750.00	2.65
C3	1.55 – 1.83+	1.52	0.003	0.047	0.050	30.40	32.34	506.60	2.35
Pedon 3									
Ap	0.00 – 0.14	1.32	0.013	0.079	0.092	14.35	16.70	101.54	6.08
Bw1	0.14 – 0.44	1.30	0.017	0.089	0.106	12.26	14.61	76.47	5.23
Bw2	0.44 – 0.79	1.32	0.021	0.102	0.123	10.73	12.94	62.86	4.86
Bw3	0.79 – 1.16	1.30	0.020	0.103	0.123	10.57	12.62	65.00	5.15
Bw4	1.16 – 1.53	1.29	0.025	0.098	0.123	10.48	13.16	51.60	3.92
Bw5	1.53 – 2.08+	1.30	0.023	0.086	0.109	11.93	15.12	56.62	3.74
Pedon 4									
Ap	0.00 – 0.17	1.37	0.016	0.076	0.092	14.89	18.03	85.63	4.75
E	0.17 – 0.36	1.34	0.018	0.097	0.115	11.65	13.81	74.44	5.39
Bt1	0.36 – 0.68	1.32	0.020	0.107	0.127	10.39	12.34	66.00	5.35
Bt2	0.68 – 1.21	1.30	0.020	0.121	0.141	9.23	10.74	65.00	6.05
Bt3	1.21 – 1.65+	1.30	0.028	0.114	0.142	9.15	10.40	46.42	4.07
Pedon 5									
Ap	0.00 – 0.15	1.34	0.014	0.094	0.108	12.41	14.26	94.29	6.71
A1	0.15 – 0.34	1.37	0.010	0.085	0.095	14.42	16.12	137.00	8.50
A2	0.34 – 0.74	1.38	0.008	0.083	0.091	15.16	16.63	172.50	10.37
A3	0.74 – 0.99	1.39	0.008	0.080	0.088	15.80	17.38	173.75	10.00
A4	0.99 – 1.14	1.39	0.014	0.083	0.097	14.32	16.74	99.29	5.92
A5	1.14 – 1.46	1.41	0.009	0.081	0.090	15.67	17.41	156.67	9.00
A6	1.46 – 1.61+	1.42	0.007	0.079	0.086	16.51	17.94	202.86	11.28
Pedon 6									
Ap	0.00 – 0.10	1.32	0.017	0.090	0.107	12.34	14.67	77.64	5.30
A1	0.10 – 0.26	1.35	0.014	0.082	0.096	14.06	16.46	96.43	5.86
A2	0.26 – 0.60	1.38	0.015	0.084	0.099	13.94	16.43	92.00	5.60
C	0.61	Weathered gneiss							
Pedon 7									
Ap	0.00 – 0.10	1.34	0.014	0.090	0.104	12.88	14.89	95.71	6.42
A1	0.10 – 0.38	1.41	0.010	0.077	0.087	13.10	18.32	141.00	7.70
A2	0.38 – 0.62	1.39	0.012	0.082	0.094	14.79	16.95	115.83	6.83
A3	0.62 – 0.91	1.39	0.009	0.072	0.081	17.16	19.31	154.44	8.00
C	0.91	Weathered gneiss							

Table 28: Simple correlations between different soil properties of profile soil samples (Relation among chemical and physical properties)

S.No.	Variables	r-values
1.	pH Vs Calcium Carbonate	0.437**
2.	CEC Vs Clay	0.487**
3.	CEC Vs Organic Carbon	0.507**
4.	R ₂ O ₃ Vs Clay	0.587**
5.	Sand Vs Silica	0.880**
6.	Sand Vs R ₂ O ₃	-0.752**
7.	Clay Vs R ₂ O ₃	0.587**
8.	Clay + Silt Vs R ₂ O ₃	0.752**
9.	Bulk density VS Organic Carbon	-0.770**
10.	Organic carbon Vs Total nitrogen	0.987**
11.	Organic carbon Vs Total phosphorus	0.798**
12.	Organic carbon Vs Total sulphur	0.910**
13.	Volume expansion Vs Clay	0.779**
14.	Volume expansion Vs Silt + Clay	0.670**
15.	Water holding capacity Vs Sand	-0.693**
16.	Water holding capacity Vs Clay	0.795**
17.	Water holding capacity Vs Silt +Clay	0.693**
18.	Water holding capacity Vs Silt	0.397*
19.	Loss on ignition Vs Clay	0.658**
20.	Loss on ignition Vs Sand	-0.547**

* Values significant at 5% level

** Values significant at 1% and 5% level.

Table 1: Meteorological data of the study area (1995-2004)

Month	*Rainfall (mm)	*Temperature (°C)		
		Maximum	Minimum	Mean
January	18.32	28.13	16.84	22.49
February	1.29	30.32	16.37	23.35
March	0.94	34.81	21.49	28.15
April	18.36	36.74	24.28	30.51
May	64.89	39.21	27.13	33.17
June	93.76	36.64	26.17	31.81
July	109.64	35.18	26.38	30.78
August	154.18	34.06	25.18	29.62
September	132.92	33.47	24.58	29.03
October	221.03	33.61	22.89	28.25
November	264.71	31.29	20.34	25.82
December	125.92	27.83	19.21	23.52
Total	1205.96	Mean 33.44	22.64	28.04

Mean annual rainfall = 1205.96 mm

Mean annual air temperature = 28.04°C

Lang's precipitation factor = 43.01

* Mean values of ten years data from 1995 to 2004

Table 3: Details of the pedons

Pedon No.	Location	Horizon	Horizon thickness (m)
1.	Ramachandrapuram	Ap	0.00 – 0.23
		Bw1	0.23 – 0.61
		Bw2	0.61 – 1.08
		Bw3	1.08 - 1.57+
2.	Nennuru	Ap	0.00 – 0.20
		A1	0.20 – 0.67
		A2	0.67 – 0.92
		C1	0.92 – 1.24
		C2	1.24 – 1.55
		C3	1.55 – 1.83+
3.	Sorakayalapalem	Ap	0.00 – 0.14
		Bw1	0.14 – 0.44
		Bw2	0.44 – 0.79
		Bw3	0.79 – 1.16
		Bw4	1.16 – 1.53
		Bw5	1.53 - 2.08+
4.	Gangireddipalli	Ap	0.00 – 0.17
		E	0.17 – 0.36
		Bt1	0.36 – 0.68
		Bt2	0.68 – 1.21
		Bt3	1.21 – 1.65+
5.	Sanjeevarayapuram	Ap	0.00 – 0.15
		A1	0.15 – 0.34
		A2	0.34 – 0.74
		A3	0.74 – 0.99
		A4	0.99 – 1.14
		A5	1.14 – 1.46
		A6	1.46 – 1.61+
6.	C.K. Palli	Ap	0.00 – 0.10
		A1	0.10 – 0.26
		A2	0.26 – 0.60
		C	0.60
7.	Nethakuppam	Ap	0.00 – 0.10
		A1	0.10 – 0.38
		A2	0.38 – 0.62
		A3	0.62 – 0.91
		C	0.91

Table 13: Per cent saturation of individual bases

Pedon No. and Horizon	Depth (m)	Ca²⁺	Mg²⁺	Na⁺	K⁺
Pedon 1					
Ap	0.00 – 0.23	51.56	23.15	7.54	2.53
Bw1	0.23 – 0.61	49.90	33.80	7.52	1.60
Bw2	0.61 – 1.08	58.08	22.34	8.12	1.90
Bw3	1.08 – 1.57+	64.16	21.87	8.02	1.86
Pedon 2					
Ap	0.00 – 0.20	50.54	27.28	6.73	1.52
A1	0.20 – 0.67	57.12	23.80	8.09	3.25
A2	0.67 – 0.92	44.78	24.88	9.02	4.48
C1	0.92 – 1.24	36.08	22.55	7.89	3.49
C2	1.24 – 1.55	26.94	22.45	11.11	3.48
C3	1.55 – 1.83+	26.29	26.29	10.84	1.10
Pedon 3					
Ap	0.00 – 0.14	43.30	27.06	12.04	6.90
Bw1	0.14 – 0.44	41.91	30.39	9.70	4.19
Bw2	0.44 – 0.79	46.38	28.99	8.41	1.12
Bw3	0.79 – 1.16	24.54	25.61	16.18	6.29
Bw4	1.16 – 1.53	26.63	24.70	16.79	3.77
Bw5	1.53 – 2.08+	45.67	25.37	9.73	3.89
Pedon 4					
Ap	0.00 – 0.17	44.66	25.92	9.32	3.98
E	0.17 – 0.36	40.96	31.88	0.11	0.68
Bt1	0.36 – 0.68	46.96	26.09	8.83	2.70
Bt2	0.68 – 1.21	53.33	30.58	10.13	4.25
Bt3	1.21 – 1.65+	52.63	23.92	9.01	2.47
Pedon 5					
Ap	0.00 – 0.15	47.40	24.52	9.48	2.94
A1	0.15 – 0.34	42.67	26.67	11.40	1.34
A2	0.34 – 0.74	49.73	27.64	5.80	2.11
A3	0.74 – 0.99	41.40	26.59	10.27	4.94
A4	0.99 – 1.14	40.96	31.88	6.35	2.80
A5	1.14 – 1.46	37.42	31.24	9.07	3.84
A6	1.46 – 1.61+	30.08	30.08	14.44	4.66
Pedon 6					
Ap	0.00 – 0.10	48.61	26.04	7.73	3.56
A1	0.10 – 0.26	45.22	26.00	6.24	2.42
A2	0.26 – 0.60	49.05	27.28	5.43	2.30
C	0.61	Weathered gneiss			
Pedon 7					
Ap	0.00 – 0.10	48.43	25.24	8.13	3.10
A1	0.10 – 0.38	44.50	27.34	9.89	4.80
A2	0.38 – 0.62	45.76	28.16	9.51	3.07
A3	0.62 – 0.91	41.49	28.49	9.82	2.50
C	0.91	Weathered gneiss			

Table 20: Total micronutrient status (mg kg⁻¹) of the soils

Pedon No. and Horizon	Depth (m)	Total micronutrients			
		Zn	Cu	*Fe (%)	Mn
Pedon 1					
Ap	0.00 – 0.23	22.25	28.50	1.41	560
Bw1	0.23 – 0.61	27.00	30.25	2.25	523
Bw2	0.61 – 1.08	30.50	32.25	2.11	474
Bw3	1.08 – 1.57+	28.25	34.00	2.05	391
Pedon 2					
Ap	0.00 – 0.20	19.25	20.75	1.60	328
A1	0.20 – 0.67	20.50	22.00	1.48	352
A2	0.67 – 0.92	17.00	20.25	1.21	281
C1	0.92 – 1.24	14.25	20.00	1.37	229
C2	1.24 – 1.55	11.25	17.00	0.27	176
C3	1.55 – 1.83+	09.50	16.25	0.29	193
Pedon 3					
Ap	0.00 – 0.14	20.75	30.50	1.52	493
Bw1	0.14 – 0.44	21.00	32.00	1.85	477
Bw2	0.44 – 0.79	23.25	33.25	2.37	495
Bw3	0.79 – 1.16	24.50	29.00	2.23	356
Bw4	1.16 – 1.53	21.50	22.00	2.81	331
Bw5	1.53 – 2.08+	20.00	22.25	2.62	319
Pedon 4					
Ap	0.00 – 0.17	26.50	27.50	1.78	620
E	0.17 – 0.36	24.00	29.50	2.00	593
Bt1	0.36 – 0.68	23.75	29.75	2.30	587
Bt2	0.68 – 1.21	23.50	30.25	2.25	491
Bt3	1.21 – 1.65+	20.00	33.00	3.17	446
Pedon 5					
Ap	0.00 – 0.15	24.75	27.00	1.52	527
A1	0.15 – 0.34	22.50	24.25	1.11	489
A2	0.34 – 0.74	22.75	25.75	0.92	452
A3	0.74 – 0.99	21.00	25.75	0.93	446
A4	0.99 – 1.14	22.25	24.00	1.59	394
A5	1.14 – 1.46	20.75	22.25	1.02	331
A6	1.46 – 1.61+	19.00	21.25	0.83	296
Pedon 6					
Ap	0.00 – 0.10	22.75	23.50	1.87	382
A1	0.10 – 0.26	20.25	22.00	1.62	346
A2	0.26 – 0.60	20.25	20.75	1.70	274
C	0.61	Weathered gneiss			
Pedon 7					
Ap	0.00 – 0.10	20.25	23.00	1.54	386
A1	0.10 – 0.38	22.00	24.75	1.15	343
A2	0.38 – 0.62	23.75	26.75	1.35	298
A3	0.62 – 0.91	22.75	27.25	1.01	221
C	0.91	Weathered gneiss			

* Total iron status is presented in percentage (%)

**Table 25: Relative proportion of clay minerals
(from X-ray diffractograms of soil clay)**

Pedon No.	Tenative soil series	Smectite	Kaolinite	Illite	Feldspars	Quartz
1.	Ramachandrapuram	69.40	9.24	6.80	14.56	Traces
2.	Nennuru	59.07	18.51	20.64	1.78	-
3.	Sorakayalapalem	-	26.56	34.38	39.06	-
4.	Gangireddipalli	32.99	41.29	20.33	3.11	2.28
5.	Sanjeevarayapuram	39.87	26.90	24.05	9.18	-
6.	C.K. Palli	-	70.80	23.74	5.46	-
7.	Nethakuppam	26.68	28.24	31.35	13.73	-

Table 18: Total macronutrients (N, P, K and sulphur) of the soils

Pedon No. and Horizon	Depth (m)	N	P	K	S
		mg kg ⁻¹			
Pedon 1					
Ap	0.00 – 0.23	630	462.5	3750	340
Bw1	0.23 – 0.61	392	375.0	4250	230
Bw2	0.61 – 1.08	364	362.5	4000	225
Bw3	1.08 – 1.57+	322	337.5	4000	220
Pedon 2					
Ap	0.00 – 0.20	560	437.5	2750	325
A1	0.20 – 0.67	420	387.5	3250	305
A2	0.67 – 0.92	322	325.0	3000	270
C1	0.92 – 1.24	252	100.0	1500	180
C2	1.24 – 1.55	140	87.5	1250	110
C3	1.55 – 1.83+	98	75.0	1000	85
Pedon 3					
Ap	0.00 – 0.14	532	400.0	2250	305
Bw1	0.14 – 0.44	420	325.0	2750	275
Bw2	0.44 – 0.79	240	275.0	3000	175
Bw3	0.79 – 1.16	250	275.0	2750	175
Bw4	1.16 – 1.53	220	262.5	2750	165
Bw5	1.53 – 2.08+	210	200.0	3000	160
Pedon 4					
Ap	0.00 – 0.17	510	437.5	2750	275
E	0.17 – 0.36	196	362.5	3250	175
Bt1	0.36 – 0.68	400	375.0	3250	260
Bt2	0.68 – 1.21	410	400.0	3500	265
Bt3	1.21 – 1.65+	410	375.0	3000	240
Pedon 5					
Ap	0.00 – 0.15	714	487.5	4000	375
A1	0.15 – 0.34	532	362.5	4250	330
A2	0.34 – 0.74	476	375.0	3500	350
A3	0.74 – 0.99	360	325.0	3250	265
A4	0.99 – 1.14	308	275.0	2750	235
A5	1.14 – 1.46	290	287.5	3000	220
A6	1.46 – 1.61+	260	150.0	3000	195
Pedon 6					
Ap	0.00 – 0.10	770	437.5	3250	360
A1	0.10 – 0.26	490	325.0	4000	280
A2	0.26 – 0.60	460	275.0	3750	240
C	0.60	Weathered gneiss			
Pedon 7					
Ap	0.00 – 0.10	670	425.0	4000	330
A1	0.10 – 0.38	450	400.0	4500	265
A2	0.38 – 0.62	370	325.0	3750	230
A3	0.62 – 0.91	238	312.5	3250	195
C	0.91	Weathered gneiss			

Table 19: Range and mean of total macronutrient content (mg kg⁻¹) of the soils

Pedon No.	Range and Mean	Total macronutrients			
		N	P	K	S
1.	Range Mean	320 - 630 427.00	337.5 - 462.5 384.37	3750 - 4250 4000.00	220 - 340 253.75
2.	Range Mean	98 - 560 282.33	75.0 - 437.5 235.41	1000 - 3250 2125.00	85 - 325 212.50
3.	Range Mean	210 - 532 312.00	200.0 - 400.0 289.58	2250 - 3000 2750.00	160 - 305 209.16
4.	Range Mean	410 - 510 385.20	375.0 - 437.5 390.00	2750 - 3500 3150.00	175 - 275 243.00
5.	Range Mean	260 - 714 420.00	150.0 - 487.5 323.21	2750 - 4250 3392.85	195 - 375 281.42
6.	Range Mean	460 - 770 573.34	275.0 - 437.5 345.83	3250 - 4000 3666.66	240 - 360 293.33
7.	Range Mean	238 - 670 432.00	312.5 - 425.0 365.62	3250 - 4500 3875.00	195 - 330 255.00

Table 21: Range and mean of total micronutrients content (mg kg⁻¹) of the soils

Pedon No.	Range and Mean	Zn	Cu	Fe(%)	Mn
1.	Range Mean	22.25 - 30.50 27.00	28.50 - 34.00 31.25	1.41 – 2.25 1.96	391.00 – 560.00 487.00
2.	Range Mean	9.50 - 20.50 15.29	16.25 – 22.00 19.38	0.27 - 1.60 1.04	176.00 – 352.00 259.83
3.	Range Mean	20.00 - 24.50 21.83	22.00 – 33.25 28.17	1.52 – 2.81 2.23	319.00 – 495.00 411.83
4.	Range Mean	20.00 – 26.50 23.55	27.50 – 33.00 30.00	1.78 – 3.17 2.30	446.00 – 620.00 547.40
5.	Range Mean	19.00 – 24.75 21.86	21.25 - 27.00 24.32	0.83 – 1.59 1.13	296.00 – 527.00 419.29
6.	Range Mean	20.25 – 22.75 20.08	20.75 – 23.50 22.08	1.62 – 1.87 1.73	274.00 – 382.00 334.00
7.	Range Mean	20.25 – 23.75 22.19	23.00 - 27.25 24.19	1.01 – 1.54 1.26	221.00 – 386.00 312.00

Table 11: Electro-chemical properties of the soils

Pedon No. and Horizon	Depth (m)	CEC	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Base saturation (%)	Ca/Mg
		(cmol(p+) kg ⁻¹)						
Pedon 1								
Ap	0.00 – 0.23	20.17	10.40	4.67	1.52	0.51	84.78	2.23
Bw1	0.23 – 0.61	25.65	12.80	8.67	1.93	0.41	92.83	1.48
Bw2	0.61 – 1.08	26.86	15.60	6.00	2.18	0.51	90.43	2.60
Bw3	1.08 – 1.57+	27.43	17.60	6.00	2.20	0.51	95.92	2.93
Pedon 2								
Ap	0.00 – 0.20	26.91	13.60	7.34	1.81	0.41	86.06	1.85
A1	0.20 – 0.67	25.21	14.40	6.00	2.04	0.82	92.26	2.40
A2	0.67 – 0.92	16.08	7.20	4.00	1.45	0.72	83.15	1.80
C1	0.92 – 1.24	17.74	6.40	4.00	1.40	0.62	70.01	1.60
C2	1.24 – 1.55	8.91	2.40	2.00	0.99	0.31	63.97	1.20
C3	1.55 – 1.83+	9.13	2.40	2.00	0.99	0.10	60.13	1.20
Pedon 3								
Ap	0.00 – 0.14	14.78	6.40	4.00	1.78	1.02	89.31	1.60
Bw1	0.14 – 0.44	21.95	9.20	6.67	2.13	0.92	86.20	1.38
Bw2	0.44 – 0.79	27.60	12.80	8.00	2.32	0.31	84.89	1.60
Bw3	0.79 – 1.16	13.04	3.20	3.34	2.11	0.82	75.69	1.08
Bw4	1.16 – 1.53	13.52	3.60	3.34	2.27	0.51	71.89	1.08
Bw5	1.53 – 2.08+	23.65	10.80	6.00	2.30	0.92	84.65	1.80
Pedon 4								
Ap	0.00 – 0.17	20.60	9.20	5.34	1.92	0.82	83.88	1.72
E	0.17 – 0.36	14.65	6.00	4.67	1.58	0.10	84.30	1.28
Bt1	0.36 – 0.68	23.00	10.80	6.00	2.03	0.62	84.57	1.80
Bt2	0.68 – 1.21	24.00	12.80	7.34	2.43	1.02	98.29	1.74
Bt3	1.21 – 1.65+	25.08	13.20	6.00	2.26	0.62	88.04	2.20
Pedon 5								
Ap	0.00 – 0.15	24.47	11.60	6.00	2.32	0.72	84.35	1.93
A1	0.15 – 0.34	15.00	6.40	4.00	1.71	0.20	82.07	1.60
A2	0.34 – 0.74	24.13	12.00	6.67	1.40	0.51	85.29	1.80
A3	0.74 – 0.99	12.56	5.20	3.34	1.29	0.62	83.20	1.56
A4	0.99 – 1.14	14.65	6.00	4.67	0.93	0.41	81.98	1.28
A5	1.14 – 1.46	10.69	4.00	3.34	0.97	0.41	81.57	1.20
A6	1.46 – 1.61+	6.65	2.00	2.00	0.96	0.31	79.25	1.00
Pedon 6								
Ap	0.00 – 0.10	23.04	11.20	6.00	1.78	0.82	85.94	1.87
A1	0.10 – 0.26	25.65	11.60	6.67	1.60	0.62	79.88	1.74
A2	0.26 – 0.60	26.91	13.20	7.34	1.46	0.62	84.06	1.80
C	0.60	Weathered gneiss						
Pedon 7								
Ap	0.00 – 0.10	26.43	12.80	6.67	2.15	0.82	84.90	1.92
A1	0.10 – 0.38	17.08	7.60	4.67	1.69	0.82	86.53	1.63
A2	0.38 – 0.62	16.61	7.60	4.67	1.58	0.51	86.45	1.63
A3	0.62 – 0.91	16.39	6.80	4.67	1.61	0.41	82.31	1.46
C	0.91	Weathered gneiss						

Table 24: d-spacing (nm) of X-Ray Diffractograms in clay fraction (less than 2 micron fraction)

Pedon No.	Calcium saturated		K-saturated				Clay mineral
	Ethylene glycol	Room temperature	Room temperature	110°C	300°C	550°C	
1.	1.721	1.430	1.235	1.002	1.002	0.995	} Smectite
	1.001	0.993	1.005	1.002	1.002	0.995	
	0.500*	0.499*	0.500*	0.501*	0.504*	0.499*	} Illite
	0.334*	0.334*	0.335*	0.335*	0.335*	0.333*	
	0.711	0.721	0.721	0.716	0.718	-	} Kaolinite
	0.357*	0.358*	0.355*	0.356*	0.357*	-	
	0.319	0.325	0.404	0.402	0.403	0.318	} Feldspars
	0.304	0.319	0.367	0.325	0.325	-	
	-	0.304	0.325	0.320	0.320	-	
	-	-	0.320	-	-	-	
	0.426	0.426	0.427	0.426	0.426	0.423	} Quartz
2.	1.649	1.473	0.999	0.999	1.000	1.000	} Smectite
	1.000	1.002	0.999	0.999	1.000	1.000	} Illite
	0.493*	0.499*	0.500*	0.500*	0.500*	0.500*	
	0.334*	0.334*	0.332*	0.332*	0.335*	0.333*	
	0.728	0.717	0.727	0.724	0.727	-	} Kaolinite
	0.336*	0.358*	0.357*	0.357*	0.357*	-	
	0.319	0.319	0.324	0.324	0.325	0.325	} Feldspars
	0.304	0.305	0.319	0.319	0.319	0.320	
	-	-	-	0.400	0.402	0.403	} Quartz
3.	-	1.457	1.002	0.996	0.999	0.987	} Smectite
	0.997	0.992	1.002	0.996	0.999	0.987	} Illite
	0.502*	0.499*	0.499*	0.500*	0.500*	0.499*	
	0.334*	0.334*	0.334*	0.333*	0.334*	0.333*	
	0.727	0.726	0.725	0.732	0.730	-	} Kaolinite
	0.355*	0.355*	0.355*	0.357*	0.357*	-	
	0.325	0.641	0.638	0.638	0.640	0.636	} Feldspars
	0.319	0.402	0.402	0.402	0.401	0.324	
	-	0.324	0.324	0.377	0.325	0.319	
	-	0.319	0.300	0.325	0.319	-	
	-	-	-	0.319	-	-	} Quartz
	-	-	-	0.425	0.425	-	

* Higher order peaks

Table 24 Contd...

Pedon No.	Calcium saturated		K-saturated				Clay mineral
	Ethylene glycol	Room temperature	Room temperature	110°C	300°C	550°C	
4.	1.674	1.494	1.001	0.998	1.001	0.992	} Smectite
	0.993	1.000	1.001	0.998	1.001	0.992	
	0.499*	0.500*	0.500*	0.498*	0.500*	0.499*	} Illite
	0.334*	0.334*	0.334*	0.333*	0.333*	0.333*	
	0.727	0.726	0.725	0.727	0.726	-	} Kaolinite
	0.358*	0.358*	0.357*	0.357*	0.356*	-	
	0.325	0.319	0.402	0.402	0.325	0.401	} Feldspars
	0.319	0.304	0.325	0.324	0.320	0.380	
	0.304	-	0.320	0.319	-	0.318	
	0.424	-	-	-	-	-	} Quartz
5.	1.638	1.529	1.324	1.005	1.891	0.983	} Smectite
	1.008	1.006	0.997	1.005	1.004	0.983	
	-	0.500*	0.498*	0.501*	0.501*	0.499*	} Illite
	0.335*	0.334*	0.334*	0.335*	0.335*	0.334*	
	0.724	0.726	0.716	0.735	0.725	-	} Kaolinite
	0.356*	0.357*	0.355*	0.356*	0.359*	-	
	0.403	0.320	0.400	0.319	0.319	0.318	} Feldspars
	0.324	0.305	0.319	-	-	-	
	0.320	-	-	-	-	-	
	0.305	-	-	-	-	-	
	-	-	0.425	0.427	-	-	} Quartz
6.	1.002	1.017	1.006	1.002	1.006	0.989	} Illite
	0.501*	0.501*	0.501*	0.502*	0.501*	0.499*	
	0.335*	0.334*	0.335*	0.334*	0.334*	0.333*	
	0.723	0.722	0.724	0.725	0.720	-	} Kaolinite
	0.359*	0.357*	0.358*	0.358*	0.356*	-	
	0.319	0.411	0.325	0.325	0.325	-	} Feldspars
	-	0.319	0.320	0.319	0.319	-	
7.	1.711	1.415	1.002	1.001	1.000	0.988	} Smectite
	0.996	0.995	1.002	0.001	1.000	0.988	
	0.499*	0.500*	0.500*	0.500*	0.499*	0.498*	} Illite
	0.334*	0.334*	0.334*	0.334*	0.332*	0.333*	
	0.716	0.736	0.726	0.726	0.713	-	} Kaolinite
	0.355*	0.358*	0.358*	0.358*	0.355*	-	
	0.304	0.319	0.403	0.402	0.324	-	} Feldspars
	-	0.304	0.325	0.325	0.319	-	
	-	-	0.319	0.319	-	-	
	-	0.425	0.421	-	-	-	} Quartz

* Higher order peaks

Table 2: Vegetation and land use of the study area

Pedon No.	Location	Natural vegetation	Land use
1.	Ramachandrapuram	<i>Calotropis gigantia</i> , <i>Cyprus rotundus</i> , <i>Cynodon dactylon</i> and <i>Parthenium hysterophorus</i>	Sugarcane, Red gram, Paddy and Groundnut
2.	Nennuru	<i>Cyprus rotundus</i> , <i>Cynadon dactylon</i> and <i>Lantana camara</i>	Groundnut, Sorghum and Coconut
3.	Sorakayalapalem	<i>Parthenium hysterophorus</i> , <i>Acalypha indica</i> and <i>Lucas aspera</i>	Mango, Groundnut and Sugarcane
4.	Gangireddipalli	<i>Cynadon dactylon</i> , <i>Parthenium hysterophorus</i> and <i>Cyprus rotundus</i>	Mango, Groundnut and Paddy
5.	Sanjeevarayapuram	<i>Azadiracta indica</i> , <i>Calotropis gigantia</i> and <i>Parthenium hysterophorus</i>	Sugarcane, Groundnut, Mango, Paddy and Coconut
6.	C.K. Palli	<i>Cyprus rotundus</i> , <i>Cynodon dactylon</i> and <i>Parthenium hysterophorus</i>	Mango, Coconut and Paddy
7.	Nethakuppam	<i>Lantana Camara</i> , <i>Cyprus rotundus</i> , <i>Cynadon dactylon</i> and <i>Tectona grandis</i>	Groundnut, Sugarcane, Coconut and Mango.

Table 6: Range and means of particle size analysis of the soils

Pedon No.	Range & Mean	Sand (2.0-0.05 mm)	Silt (0.05 -0.002mm)	Clay (< 0.002 mm)	Sand/ Silt	Silt/Clay	Sand / Silt + Clay
		(%)					
1.	Range	40.19 – 57.03	15.84 – 24.22	27.13 – 35.64	1.66 – 3.60	0.58 – 0.71	0.33 – 0.72
	Mean	48.07	20.34	31.59	2.53	0.64	3.87
2.	Range	54.38 – 89.82	4.97 – 17.46	4.33 – 29.84	3.11 – 18.07	0.34 – 1.43	1.19 – 8.82
	Mean	74.22	9.85	15.93	9.52	0.81	4.47
3.	Range	16.81 – 24.59	48.64 – 56.53	22.28 – 28.83	0.31 – 0.48	1.73 – 2.38	0.20 – 0.33
	Mean	20.89	52.73	26.38	0.40	2.02	0.27
4.	Range	42.49 – 58.26	19.25 – 26.65	18.83 – 32.05	1.59 – 3.03	0.79 – 1.40	0.74 – 1.40
	Mean	49.50	24.42	26.09	2.08	0.97	1.01
5.	Range	43.67 – 64.86	20.13 – 31.02	15.01 – 28.13	1.49 – 3.22	1.00 – 1.40	0.78 – 1.85
	Mean	55.11	24.98	19.92	2.29	1.28	1.29
6.	Range	54.67 – 64.67	13.47 – 22.51	19.98 – 22.82	2.43 – 4.80	0.62 – 1.10	1.21 – 1.83
	Mean	59.16	19.29	21.55	3.30	0.90	1.48
7.	Range	59.86 – 66.24	11.72 – 18.31	20.11 – 24.15	3.36 – 5.65	0.53 – 0.91	1.49 – 1.96
	Mean	62.28	15.71	22.02	4.10	0.72	1.66

Table 12: Range and mean of electro-chemical properties of the soils

Pedon No.	Range & Mean	CEC	Ca²⁺	Mg²⁺ (cmol(p+)^{kg}⁻¹)	Na⁺	K⁺	Base saturation (%)	Ca/Mg
1.	Range	20.17 - 27.43	10.40 - 17.60	4.67 - 8.67	1.52 - 2.20	0.41 - 0.51	84.78 - 95.92	1.48 - 2.93
	Mean	25.03	14.10	6.34	1.96	0.49	90.99	2.31
2.	Range	8.91 - 26.91	2.40 - 14.40	2.00 - 7.34	0.99 - 2.04	0.10 - 0.82	60.13 - 92.26	1.20 - 2.40
	Mean	17.33	7.73	4.22	1.45	0.60	75.93	1.68
3.	Range	13.04 - 27.60	3.20 - 12.80	3.34 - 8.00	1.78 - 2.32	0.31 - 1.02	71.89 - 89.31	1.08 - 1.60
	Mean	19.09	7.67	5.23	2.15	0.75	82.11	1.30
4.	Range	14.65 - 25.08	6.00 - 13.20	4.67 - 7.34	1.58 - 2.43	0.10 - 1.02	83.88 - 98.29	1.28 - 2.20
	Mean	21.47	10.40	4.67	2.04	0.64	87.82	1.75
5.	Range	6.65 - 24.47	2.00 - 12.00	2.00 - 6.67	0.93 - 2.32	0.20 - 0.72	79.25 - 85.29	1.00 - 1.93
	Mean	15.45	6.74	4.29	1.37	0.45	82.53	1.48
6.	Range	23.04 - 26.91	11.20 - 13.20	6.00 - 7.34	1.46 - 1.78	0.62 - 0.82	79.88 - 85.94	1.74 - 1.87
	Mean	25.20	12.00	6.67	1.61	0.69	83.29	1.80
7.	Range	16.39 - 26.43	6.80 - 12.80	4.67 - 6.67	1.58 - 2.15	0.41 - 0.82	82.30 - 86.46	1.46 - 1.92
	Mean	19.13	8.70	5.12	1.76	0.64	85.03	1.66

Table 10: Range and mean of physico-chemical properties of the soils

Pedon No.	Range & Mean	Organic carbon (%)	Total nitrogen (%)	C/N Ratio	CaCO ₃	pH (1:25)		EC (dSm ⁻¹)
						H ₂ O	1N KCl	
1.	Range	0.32 - 0.56	0.032 - 0.063	8.89 - 10.00	0.85 - 1.83	8.03 - 8.26	6.31 - 6.82	0.10 - 0.18
	Mean	0.39	0.043	9.26	1.37	8.14	6.63	0.13
2.	Range	0.12 - 0.54	0.010 - 0.056	6.80 - 12.00	0.45 - 1.38	7.67 - 8.14	6.07 - 6.81	0.01 - 0.04
	Mean	0.28	0.029	9.61	0.90	7.96	6.43	0.02
3.	Range	0.18 - 0.50	0.021 - 0.053	8.57 - 9.76	1.00 - 1.25	6.86 - 7.56	5.41 - 6.74	0.02 - 0.05
	Mean	0.29	0.031	9.35	1.10	7.21	6.09	0.04
4.	Range	0.15 - 0.47	0.020 - 0.051	7.50 - 10.00	0.53 - 1.40	6.79 - 7.03	5.92 - 6.51	0.04 - 0.09
	Mean	0.36	0.038	9.20	0.91	7.05	6.31	0.07
5.	Range	0.24 - 0.71	0.026 - 0.071	7.92 - 10.00	0.93 - 1.18	7.65 - 8.23	6.76 - 7.26	0.02 - 0.08
	Mean	0.39	0.042	9.20	1.07	8.04	7.09	0.04
6.	Range	0.44 - 0.77	0.046 - 0.077	9.57 - 10.00	-	7.16 - 7.28	6.13 - 6.26	0.01 - 0.04
	Mean	0.56	0.057	9.72	-	7.23	6.22	0.02
7.	Range	0.23 - 0.65	0.024 - 0.067	9.46 - 10.00	0.50 - 0.85	7.15 - 7.59	5.76 - 6.59	0.04 - 0.12
	Mean	0.42	0.043	9.69	0.66	7.40	6.16	0.07

Table 8: Range and mean of physical properties of the soils

Pedon No.	Range & Mean	Bulk density (Mgm⁻³)	Particle density (Mgm⁻³)	Water holding capacity (%)	Pore space (%)	Volume expansion (%)	WHC/Clay	LOI (%)
1.	Range	1.47 - 1.66	2.46 - 2.52	38.15 - 47.81	50.06 - 57.98	17.24 - 26.32	4.20 - 6.85	1.34 - 1.41
	Mean	1.56	2.5	42.94	55.60	21.74	5.89	1.36
2.	Range	1.50 - 1.65	2.51 - 2.65	19.96 - 39.41	20.51 - 46.86	2.91 - 18.24	2.10 - 6.30	1.32 - 4.61
	Mean	1.58	2.57	28.68	31.84	9.64	4.02	2.54
3.	Range	1.45 - 1.62	2.46 - 2.56	35.67 - 38.89	35.81 - 43.71	15.21 - 18.13	3.90 - 5.70	1.35 - 1.60
	Mean	1.56	2.52	37.60	39.85	17.12	4.66	1.43
4.	Range	1.49 - 1.60	2.47 - 2.52	31.37 - 44.64	50.14 - 53.64	11.23 - 22.64	13.30 - 5.60	1.36 - 1.67
	Mean	1.55	2.49	38.26	52.53	17.58	4.81	1.49
5.	Range	1.47 - 1.65	2.44 - 2.61	30.02 - 38.51	45.20 - 56.77	7.94 - 17.35	2.85 - 5.85	1.37 - 2.00
	Mean	1.57	2.53	33.00	50.51	12.29	4.29	1.7
6.	Range	1.48 - 1.55	2.49 - 2.52	32.46 - 35.91	50.63 - 52.81	12.81 - 16.36	3.15 - 3.85	1.52 - 1.62
	Mean	1.52	2.51	33.88	51.57	14.75	3.57	1.57
7.	Range	1.49 - 1.61	2.39 - 2.59	32.96 - 36.03	52.07 - 54.19	15.06 - 17.00	3.15 - 4.10	1.49 - 1.64
	Mean	1.55	2.49	34.41	53.02	15.56	3.65	1.57

Table 15: Range and mean of chemical composition of the soils (%)

Pedon Number	Range & Mean	SiO₂	R₂O₃	Fe₂O₃	Al₂O₃	P₂O₅	K₂O	Na₂O	CaO	MgO
1.	Range	80.0 - 83.60	9.15 - 13.25	2.01 – 3.22	7.14– 10.23	0.08 - 0.11	0.45 - 0.51	0.12 - 0.17	2.63 -2.98	0.87 - 1.49
	Mean	81.25	11.82	2.80	9.03	0.09	0.48	0.14	2.80	1.09
2.	Range	84.2 - 91.10	5.25 - 9.75	0.39-2.29	4.29-7.46	0.02 - 0.10	0.12 - 0.39	0.06 - 0.12	0.86 - 2.28	0.50 -1.12
	Mean	88.03	7.0	1.48	5.52	0.05	0.25	0.09	1.45	0.73
3.	Range	78.20 - 79.20	10.25 - 14.00	2.17-4.02	8.08-10.54	0.05 - 0.09	0.27 - 0.36	0.10 - 0.15	1.40 - 2.28	0.62 - 0.87
	Mean	78.38	12.67	3.20	9.47	0.06	0.33	0.12	0.23	0.70
4.	Range	78.30 - 82.50	10.25 -16.25	2.54-4.53	7.71-12.29	0.08 - 0.10	0.33 - 0.42	0.06 - 0.13	1.75 - 2.45	0.75 - 1.37
	Mean	79.82	13.8	3.29	10.51	0.09	0.38	0.10	2.03	0.95
5.	Range	80.40 - 85.10	9.25 - 11.75	1.19-2.27	8.06-9.57	0.03 - 0.11	0.33 - 0.51	0.08 - 0.15	1.23 - 2.28	0.50 - 0.87
	Mean	83.18	10.14	1.62	8.52	0.72	0.40	0.11	1.70	0.69
6.	Range	79.50 - 83.2	10.75 - 11.75	2.31-2.67	8.44-9.08	0.06 - 0.10	0.39 - 0.48	0.08 - 0.11	1.05 - 2.24	0.87 - 1.25
	Mean	81.33	11.17	2.47	8.70	0.08	0.44	0.09	1.80	1.08
7.	Range	80.30 - 84.90	8.75 - 11.25	1.44-2.20	7.31-9.05	0.07 - 0.10	0.39 - 0.54	0.08 - 0.13	1.58 - 2.28	0.62 - 0.87
	Mean	83.13	9.93	1.80	8.14	0.08	0.47	0.11	1.9	0.78

Table 4: Summary of the morphological characters of the pedons*

Ped-on no. & Hori- zon	Depth (m)	Colour		Tex- ture	Structure			Consistence			Effe- rves- cence	Boundary		Cutans			Pores		Roots		Other features
		Moist	Dry		S	G	T	D	M	W		D	T	Ty	Th	Q	S	Q	S	Q	
Pedon 1																					
Ap	0.00 – 0.23	10 YR 3/2	10 YR 3/2	scl	m	2	sbk	sh	fi	sssp	-	d	w	-	-	-	f	f	m	f	-
Bw1	0.23 – 0.61	10 YR 2/2	10 YR 2/2	scl	m	1	sbk	h	fi	sssp	-	d	w	-	-	-	f	f	-	-	-
Bw2	0.61 – 1.08	10 YR 3/1	10 YR 3/2	cl	f	1	abk	h	vfi	sp	-	d	w	-	-	-	f	f	-	-	Slicken- sides
Bw3	1.08 – 1.57+	10 YR 4/6	10 YR 4/4	cl	m	2	sbk	sh	vfi	sssp	es	c	s	-	-	-	f	f	-	-	
Pedon 2																					
Ap	0.00 – 0.20	10 YR 3/1	10 YR 3/2	scl	m	2	sbk	sh	fr	sssp	-	c	s	-	-	-	f	f	f	f	-
A1	0.20 – 0.67	7.5 YR 4/4	7.5 YR 4/4	scl	m	2	sbk	sh	fr	sssp	-	d	w	-	-	-	f	f	-	-	-
A2	0.67 – 0.92	7.5 YR 4/4	7.5 YR 4/4	sl	m	2	sbk	sh	fr	sssp	-	d	w	-	-	-	f	f	-	-	-
C1	0.92 – 1.24	7.5 YR 4/6	7.5 YR 4/6	ls	c	1	cr	l	vfr	sopo	-	d	w	-	-	-	f	f	-	-	-
C2	1.24 – 1.55	7.5 YR 5/6	7.5 YR 6/4	s	c	0	sg	l	l	sopo	-	c	s	-	-	-	c	c	-	-	-
C3	1.55 – 1.83+	7.5 YR 5/6	7.5 YR 6/4	s	c	0	sg	l	l	sopo	-	d	w	-	-	-	c	c	-	-	-
Pedon 3																					
Ap	0.00 – 0.14	7.5 YR 5/6	7.5 YR 5/6	sil	f	1	cr	l	vfr	sopo	-	c	s	-	-	-	m	c	f	c	-
Bw1	0.14 – 0.44	7.5 YR 5/4	7.5 YR 5/6	sicl	m	2	sbk	sh	fi	sssp	-	d	w	-	-	-	f	c	-	-	-
Bw2	0.44 – 0.79	7.5 YR 4/6	7.5 YR 5/6	cl	m	2	sbk	h	fi	sp	-	d	w	-	-	-	f	c	-	-	-
Bw3	0.79 – 1.16	7.5 YR 4/4	7.5 YR 5/4	sicl	m	2	sbk	s	fr	sssp	-	d	w	-	-	-	f	c	-	-	-
Bw4	1.16 – 1.53	7.5 YR 4/4	7.5 YR 5/4	sicl	m	2	sbk	s	fr	sssp	-	c	s	-	-	-	f	c	-	-	-
Bw5	1.53 – 2.08+	7.5 YR 3/4	7.5 YR 6/4	cl	m	3	sbk	h	fi	sp	-	d	w	-	-	-	f	c	-	-	-
Pedon 4																					
Ap	0.00 - 0.17	10 YR 4/3	10 YR 4/3	scl	f	1	sbk	sh	fi	sssp	-	c	s	-	-	-	f	f	f	f	-
E	0.17 – 0.36	7.5 YR 5/6	7.5 YR 5/6	sl	f	1	sbk	h	fr	sopo	-	c	s	-	-	-	-	-	-	-	-
Bt1	0.36 – 0.68	7.5 YR 3/4	7.5 YR 5/4	scl	m	2	sbk	h	fi	sssp	-	c	s	-	-	-	-	-	-	-	-
Bt2	0.68 – 1.21	2.5 YR 4/2	2.5 YR 4/2	cl	c	2	sbk	h	fi	sssp	-	d	w	-	-	-	-	-	-	-	-
Bt3	1.21 – 1.65+	2.5 YR 3/6	2.5 YR 3/6	cl	c	3	sbk	h	fi	sssp	-	d	w	-	-	-	-	-	-	-	-

Table 4 Contd...

Ped-on no. & Horizon	Depth (m)	Colour		Tex-ture	Structure			Consistence			Effe-rves-cence	Boundary		Cutans			Pores		Roots		Other features
		Moist	Dry		S	G	T	D	M	W		D	T	Ty	Th	Q	S	Q	S	Q	
Pedon 5																					
Ap	0.00 – 0.15	10 YR 3/3	10 YR 3/3	cl	m	2	abk	h	fi	sssp	-	c	s	-	-	-	-	-	f	f	-
A1	0.15 – 0.34	10 YR 4/4	10 YR 6/4	l	m	2	sbk	h	fr	sssp	-	c	s	-	-	-	-	-	-	-	-
A2	0.34 – 0.74	7.5 YR 4/4	7.5 YR 4/4	scl	m	2	abk	h	fi	sssp	-	c	s	-	-	-	-	-	-	-	-
A3	0.74 – 0.99	7.5 YR 4/6	7.5 YR 4/4	sl	f	1	sbk	l	fr	sopo	-	c	s	-	-	-	-	-	-	-	-
A4	0.99 – 1.14	7.5 YR 4/4	7.5 YR 3/4	sl	f	1	sbk	l	fr	sopo	-	c	s	-	-	-	-	-	-	-	-
A5	1.14 – 1.46	5 YR 4/6	5 YR 5/6	sl	m	2	sbk	sh	fr	sopo	-	c	s	-	-	-	-	-	-	-	-
A6	1.46 – 1.61+	5 YR 4/6	5 YR 4/6	sl	m	2	sbk	sh	fr	sopo	-	c	s	-	-	-	-	-	-	-	-
Pedon 6																					
Ap	0.00 – 0.10	10 YR 4/4	10 YR 5/4	scl	f	1	sbk	h	fr	sssp	-	c	s	-	-	-	f	f	f	f	-
A1	0.10 – 0.26	7.5 YR 4/4	7.5 YR 5/4	scl	m	2	sbk	vh	fi	sssp	-	c	s	-	-	-	-	-	-	-	-
A2	0.26 – 0.60	2.5 YR 3/6	2.5 YR 3/6	scl	m	2	sbk	vh	fi	sssp	-	c	s	-	-	-	-	-	-	-	-
C	0.60	Weathered gneiss																			
Pedon 7																					
Ap	0.00 – 0.10	10 YR 3/2	10 YR 3/2	scl	m	2	sbk	sh	fr	sssp	-	c	s	-	-	-	f	f	f	f	-
A1	0.10 – 0.38	10 YR 4/4	10 YR 5/4	scl	m	2	sbk	h	fi	sssp	-	c	s	-	-	-	-	-	-	-	-
A2	0.38 – 0.62	7.5 YR 4/6	7.5 YR 4/6	scl	f	2	sbk	h	fi	sp	-	c	s	-	-	-	-	-	-	-	-
A3	0.62 – 0.91	7.5 YR 4/4	7.5 YR 4/4	scl	f	2	sbk	h	fi	sssp	-	c	s	-	-	-	-	-	-	-	-
C	0.91	Weathered gneiss																			

*** Symbols used are according to soil Survey Manual (Soil Survey Staff, 1951)**

Texture : c - clay, cl - clay loam, l - loam, s - sand, sl - sandy loam, scl - sandy clay loam sc - sandy clay, ls - loamy sand,

Structure : Size (S) - vf - very fine, f - fine, m - medium, c - coarse ; Grade (G) - O - structureless, 1 - weak, 2 - moderate, 3 - strong ; Type (T) cr - crumb, sg - single grain, abk - angular blocky, sbk - sub-angular blocky.

Consistence :

Dry : s - soft, l - loose, sh - slightly hard, h - hard, vh - very hard,

Moist : l - loose, fr - friable, fi - firm, vfi - very firm

Wet : so - non-sticky, ss - slightly sticky, sticky - s, vs - very sticky ; po - non plastic ps - slightly plastic, p - plastic, vp - very plastic.

Cutans Ty - Type - t - Argillan, Th - Thickness tn - thin, thick - th ; Quantity (Q) p - patchy , c - Continuous.

Pores : Size (S) f - fine, m - medium, c - coarse ; Q - Quantity f - few, c - common, m - many.

Roots : Size (S) f - fine, m - medium, c - coarse ; Q -Quantity f - few, c - common, m - many.

Effervescence : es - strong effervescence, ev - violent effervescence.

Boundary: D - Distinctness, c - clear, g - gradual, d - diffuse.

T - Topography ; s - smooth ; w - wavy.

Table 5: Particle size analysis of soils (< 2 mm size)

Pedon No. & Horizon	Depth (m)	Sand (2.0-0.05 mm)	Silt (0.05 -0.002mm) (%)	Clay (< 0.002 mm)	Textural class	Sand / Silt	Silt / Clay	Sand / Silt + Clay
Pedon 1								
Ap	0.00 – 0.23	57.03	15.84	27.13	scl	3.60	0.58	1.33
Bw1	0.23 – 0.61	53.42	17.12	29.46	scl	3.12	0.58	1.15
Bw2	0.61 – 1.08	41.64	24.22	34.14	cl	1.72	0.71	0.72
Bw3	1.08 – 1.57+	40.19	24.17	35.64	cl	1.66	0.68	0.67
Pedon 2								
Ap	0.00 – 0.20	54.38	17.46	28.16	scl	3.11	0.62	1.19
A1	0.20 – 0.67	60.16	10.00	29.84	scl	6.02	0.34	1.51
A2	0.67 – 0.92	69.64	12.07	18.29	sl	5.77	0.66	2.29
C1	0.92 – 1.24	81.83	8.41	9.76	ls	9.73	0.86	4.50
C2	1.24 - 1.55	89.46	6.21	4.33	s	14.41	1.43	8.49
C3	1.55 – 1.83+	89.82	4.97	5.21	s	18.07	0.95	8.82
Pedon 3								
Ap	0.00 - 0.14	24.59	53.13	22.28	sil	0.46	2.38	0.33
Bw1	0.14 – 0.44	18.76	56.53	24.71	sicl	0.33	2.29	0.23
Bw2	0.44 – 0.79	23.28	48.64	28.08	cl	0.48	1.73	0.30
Bw3	0.79 – 1.16	18.93	54.61	26.46	sicl	0.35	2.07	0.23
Bw4	1.16 – 1.53	16.81	54.36	28.83	sicl	0.31	1.89	0.20
Bw5	1.53 – 2.08+	22.96	49.12	27.92	cl	0.47	1.76	0.30
Pedon 4								
Ap	0.00 – 0.17	58.26	19.25	22.49	scl	3.03	0.86	1.40
E	0.17 – 0.36	54.82	26.35	18.83	sl	2.08	1.40	1.21
Bt1	0.36 – 0.68	49.16	24.64	26.20	scl	2.00	0.94	0.97
Bt2	0.68 – 1.21	42.76	25.19	32.05	cl	1.70	0.79	0.75
Bt3	1.21 – 1.65+	42.49	26.65	30.86	cl	1.59	0.86	0.74

Table 5 Contd...

Pedon No. & Horizon	Depth (m)	Sand (2.0-0.05 mm)	Silt (0.05 -0.002mm) (%)	Clay (< 0.002 mm)	Textural class	Sand / Silt	Silt / Clay	Sand / Silt + Clay
Pedon 5								
Ap	0.00 – 0.15	43.67	28.20	28.13	cl	1.55	1.00	0.78
A1	0.15 – 0.34	46.19	31.02	22.79	l	1.49	1.36	0.86
A2	0.34 – 0.74	51.83	26.58	21.59	scl	1.95	1.23	1.08
A3	0.74 – 0.99	58.03	23.11	18.86	sl	2.51	1.23	1.38
A4	0.99 – 1.14	58.85	24.02	17.13	sl	2.45	1.40	1.43
A5	1.14 – 1.46	62.27	21.81	15.92	sl	2.86	1.37	1.65
A6	1.46 – 1.61+	64.86	20.13	15.01	sl	3.22	1.34	1.85
Pedon 6								
Ap	0.00 – 0.10	54.67	22.51	22.82	scl	2.43	0.99	1.21
A1	0.10 – 0.26	58.13	21.89	19.98	scl	2.66	1.10	1.39
A2	0.26 – 0.60	64.67	13.47	21.86	scl	4.80	0.62	1.83
C	0.60	Weathered gneiss						
Pedon 7								
Ap	0.00 – 0.10	59.86	15.99	24.15	scl	3.74	0.66	1.49
A1	0.10 – 0.38	66.24	11.72	22.04	scl	5.65	0.53	1.96
A2	0.38 – 0.62	61.43	16.81	21.76	scl	3.65	0.77	1.59
A3	0.62 – 0.91	61.58	18.31	20.11	scl	3.36	0.91	1.60
C	0.91	Weathered gneiss						

Table 7: Physical characteristics of the soils

Pedon No. & Horizon	Depth (m)	Bulk density (Mgm⁻³)	Particle density (Mgm⁻³)	Water holding capacity (%)	Pore space (%)	Volume expansion (%)	WHC/Clay	LOI (%)
Pedon 1								
Ap	0.00 – 0.23	1.47	2.46	38.15	50.06	17.24	1.41	4.20
Bw1	0.23 – 0.61	1.48	2.51	39.36	56.37	18.21	1.34	5.95
Bw2	0.61 – 1.08	1.61	2.48	46.43	57.91	25.18	1.36	6.55
Bw3	1.08 – 1.57+	1.66	2.52	47.81	57.98	26.32	1.34	6.85
Pedon 2								
Ap	0.00 – 0.20	1.50	2.53	38.57	46.86	17.36	1.37	6.15
A1	0.20 – 0.67	1.50	2.51	39.41	44.32	18.24	1.32	6.30
A2	0.67 – 0.92	1.53	2.56	31.24	36.83	10.86	1.71	4.00
C1	0.92 – 1.24	1.62	2.65	22.64	21.86	5.23	2.32	3.25
C2	1.24 – 1.55	1.65	2.58	19.96	20.64	2.91	4.61	2.10
C3	1.55 – 1.83+	1.65	2.56	20.23	20.51	3.26	3.88	2.30
Pedon 3								
Ap	0.00 – 0.14	1.45	2.48	35.67	35.81	15.21	1.60	3.90
Bw1	0.14 – 0.44	1.49	2.53	36.16	38.67	17.11	1.46	4.25
Bw2	0.44 – 0.79	1.56	2.46	38.54	39.13	17.27	1.37	5.70
Bw3	0.79 – 1.16	1.62	2.54	38.03	39.14	17.05	1.44	4.20
Bw4	1.16 – 1.53	1.62	2.56	38.89	42.62	18.13	1.35	5.05
Bw5	1.53 – 2.08+	1.62	2.53	38.26	43.71	17.92	1.37	4.95
Pedon 4								
Ap	0.00 – 0.17	1.49	2.48	35.46	53.64	15.86	1.58	4.15
E	0.17 – 0.36	1.55	2.51	31.37	50.14	11.23	1.67	3.30
Bt1	0.36 – 0.68	1.56	2.52	37.99	51.88	17.31	1.45	5.45
Bt2	0.68 – 1.21	1.57	2.47	44.64	53.47	22.64	1.39	5.60
Bt3	1.21 – 1.65+	1.60	2.49	41.86	53.52	20.86	1.36	5.55

Table 7 Contd...

Pedon No. & Horizon	Depth (m)	Bulk density (Mgm ⁻³)	Particle density (Mgm ⁻³)	Water holding capacity (%)	Pore space (%)	Volume expansion (%)	WHC/Clay	LOI (%)
Pedon 5								
Ap	0.00 – 0.15	1.47	2.46	38.51	56.77	17.35	1.37	5.85
A1	0.15 – 0.34	1.49	2.44	35.86	54.09	15.96	1.57	5.20
A2	0.34 – 0.74	1.54	2.46	33.14	54.02	14.81	1.53	4.35
A3	0.74 – 0.99	1.56	2.55	31.62	49.86	11.26	1.68	4.25
A4	0.99 – 1.14	1.64	2.61	31.28	48.31	10.52	1.83	4.00
A5	1.14 – 1.46	1.64	2.59	30.54	45.29	8.21	1.92	3.50
A6	1.46 – 1.61+	1.65	2.58	30.02	45.20	7.94	2.00	2.85
Pedon 6								
Ap	0.00 – 0.10	1.48	2.52	35.91	52.81	16.36	1.57	3.85
A1	0.10 – 0.26	1.54	2.49	32.46	50.63	12.81	1.62	3.15
A2	0.26 – 0.60	1.55	2.51	33.26	51.27	15.07	1.52	3.70
C	0.60	Weathered gneiss						
Pedon 7								
Ap	0.00 – 0.10	1.49	2.59	36.03	54.19	17.00	1.49	4.10
A1	0.10 – 0.38	1.52	2.47	35.19	53.61	15.08	1.60	3.80
A2	0.38 – 0.62	1.58	2.39	33.47	52.22	15.08	1.54	3.55
A3	0.62 – 0.91	1.61	2.51	32.96	52.07	15.06	1.64	3.15
C	0.91	Weathered gneiss						

Table 9: Physico-chemical Properties of the soil

Pedon No. & Horizon	Depth (m)	Organic carbon (%)	Total Nitrogen (%)	C/N Ratio	CaCO ₃	pH (1:2.5)		EC (dSm ⁻¹)
						H ₂ O	1N KCl	
Pedon 1								
Ap	0.00 – 0.23	0.56	0.063	8.89	0.85	8.12	6.63	0.10
Bw1	0.23 – 0.61	0.35	0.039	8.97	1.38	8.26	6.82	0.11
Bw2	0.61 – 1.08	0.33	0.036	9.17	1.83	8.03	6.31	0.14
Bw3	1.08 – 1.57+	0.32	0.032	10.00	1.43	8.16	6.75	0.18
Pedon 2								
Ap	0.00 – 0.20	0.54	0.056	9.64	1.38	8.04	6.52	0.01
A1	0.20 – 0.67	0.40	0.042	9.52	1.18	8.10	6.72	0.01
A2	0.67 – 0.92	0.31	0.032	9.69	1.03	8.14	6.81	0.02
C1	0.92 – 1.24	0.17	0.025	6.80	0.83	7.67	6.07	0.03
C2	1.24 - 1.55	0.14	0.014	10.00	0.50	7.86	6.12	0.03
C3	1.55 – 1.83+	0.12	0.010	12.00	0.45	7.93	6.36	0.04
Pedon 3								
Ap	0.00 - 0.14	0.50	0.053	9.43	1.05	6.86	5.41	0.02
Bw1	0.14 – 0.44	0.41	0.042	9.76	1.05	6.93	5.67	0.04
Bw2	0.44 – 0.79	0.23	0.024	9.58	1.00	7.31	5.98	0.04
Bw3	0.79 – 1.16	0.23	0.025	9.20	1.08	7.25	6.03	0.05
Bw4	1.16 – 1.53	0.21	0.022	9.55	1.18	7.56	6.74	0.04
Bw5	1.53 – 2.08+	0.18	0.021	8.57	1.25	7.35	6.73	0.03

Table 9 Contd..

Pedon No. & Horizon	Depth (m)	Organic carbon (%)	Total Nitrogen (%)	C/N Ratio	CaCO₃	pH (1:2.5)		EC (dSm⁻¹)
						H₂O	1N KCl	
Pedon 4								
Ap	0.00 – 0.17	0.47	0.051	9.22	1.40	6.79	5.92	0.04
E	0.17 – 0.36	0.15	0.020	7.50	0.80	7.20	6.46	0.08
Bt1	0.36 – 0.68	0.39	0.040	9.75	0.53	7.05	6.29	0.06
Bt2	0.68 – 1.21	0.41	0.041	10.00	-	7.20	6.51	0.08
Bt3	1.21 – 1.65+	0.39	0.041	9.51	-	7.03	6.38	0.09
Pedon 5								
Ap	0.00 – 0.15	0.71	0.071	10.00	1.30	7.65	6.76	0.02
A1	0.15 – 0.34	0.42	0.053	7.92	1.18	8.21	7.14	0.02
A2	0.34 – 0.74	0.44	0.048	9.17	1.13	8.23	7.26	0.03
A3	0.74 – 0.99	0.35	0.036	9.72	1.05	8.17	7.19	0.05
A4	0.99 – 1.14	0.26	0.031	8.39	0.98	8.04	7.16	0.08
A5	1.14 – 1.46	0.29	0.029	10.00	0.93	7.94	7.02	0.05
A6	1.46 – 1.61+	0.24	0.026	9.23	0.93	8.02	7.11	0.06
Pedon 6								
Ap	0.00 – 0.10	0.77	0.077	10.00	-	7.16	6.26	0.01
A1	0.10 – 0.26	0.47	0.049	9.59	-	7.24	6.13	0.02
A2	0.26 – 0.60	0.44	0.046	9.57	-	7.28	6.26	0.04
C	0.60	Weathered gneiss						
Pedon-7								
Ap	0.00 – 0.10	0.65	0.067	9.70	0.50	7.45	6.59	0.04
A1	0.10 – 0.38	0.45	0.045	10.00	0.58	7.15	5.76	0.05
A2	0.38 – 0.62	0.35	0.037	9.46	0.70	7.42	6.06	0.08
A3	0.62 – 0.91	0.23	0.024	9.58	0.85	7.59	6.21	0.12
C	0.91	Weathered gneiss						

Table 14: Chemical composition of the soils (%)

Pedon No. & Horizon	Depth (m)	SiO₂	R₂O₃	Fe₂O₃	Al₂O₃	P₂O₅	K₂O	Na₂O	CaO	MgO
Pedon 1										
Ap	0.00 – 0.23	83.60	9.15	2.01	7.14	0.11	0.45	0.12	2.98	1.49
Bw1	0.23 – 0.61	81.30	12.15	3.22	8.93	0.09	0.51	0.17	2.80	1.00
Bw2	0.61 – 1.08	80.10	13.25	3.02	10.23	0.08	0.48	0.13	2.63	0.87
Bw3	1.08 – 1.57+	80.00	12.75	2.93	9.82	0.08	0.48	0.14	2.80	1.00
Pedon 2										
Ap	0.00 – 0.20	84.20	9.75	2.29	7.46	0.10	0.33	0.11	2.28	1.12
A1	0.20 – 0.67	85.90	8.25	2.11	6.14	0.09	0.39	0.12	2.10	0.87
A2	0.67 – 0.92	87.70	6.75	1.73	5.02	0.07	0.36	0.09	1.40	0.75
C1	0.92 – 1.24	89.20	6.25	1.96	4.29	0.02	0.18	0.08	1.23	0.62
C2	1.24 – 1.55	90.10	5.75	0.39	5.36	0.02	0.15	0.06	0.86	0.50
C3	1.55 – 1.83+	91.10	5.25	0.42	4.83	0.02	0.12	0.06	0.86	0.50
Pedon 3										
Ap	0.00 – 0.14	79.20	10.25	2.17	8.08	0.09	0.27	0.10	2.28	0.87
Bw1	0.14 – 0.44	78.20	11.75	2.64	9.11	0.07	0.33	0.14	1.93	0.62
Bw2	0.44 – 0.79	79.10	13.75	3.39	10.36	0.06	0.36	0.15	1.75	0.62
Bw3	0.79 – 1.16	78.00	13.75	3.21	10.54	0.06	0.33	0.11	1.58	0.75
Bw4	1.16 – 1.53	77.60	14.00	4.02	9.98	0.06	0.33	0.12	1.40	0.75
Bw5	1.53 – 2.08+	78.20	12.50	3.75	8.75	0.05	0.36	0.11	1.40	0.62
Pedon 4										
Ap	0.00 – 0.17	82.50	10.25	2.54	7.71	0.10	0.33	0.08	2.45	1.37
E	0.17 – 0.36	80.80	12.75	2.86	9.89	0.08	0.39	0.06	2.10	1.00
Bt1	0.36 – 0.68	79.20	14.25	3.29	10.96	0.09	0.39	0.10	1.93	0.87
Bt2	0.68 – 1.21	78.30	15.50	3.21	12.29	0.09	0.42	0.11	1.93	0.75
Bt3	1.21 – 1.65+	78.30	16.25	4.53	11.72	0.09	0.36	0.13	1.75	0.75

Table 14 Contd...

Pedon No. & Horizon	Depth (m)	SiO ₂	R ₂ O ₃	Fe ₂ O ₃	Al ₂ O ₃	P ₂ O ₅	K ₂ O	Na ₂ O	CaO	MgO
Pedon 5										
Ap	0.00 – 0.15	80.40	11.75	2.18	9.57	0.11	0.48	0.06	2.28	0.75
A1	0.15 – 0.34	82.40	10.25	1.59	8.66	0.08	0.51	0.08	1.93	0.87
A2	0.34 – 0.74	82.70	9.75	1.32	8.43	0.09	0.42	0.13	1.58	0.75
A3	0.74 – 0.99	83.60	9.50	1.33	8.17	0.07	0.39	0.15	1.75	0.75
A4	0.99 – 1.14	83.50	10.75	2.27	8.48	0.06	0.33	0.11	1.40	0.62
A5	1.14 – 1.46	84.60	9.75	1.46	8.29	0.07	0.36	0.11	1.23	0.62
A6	1.46 – 1.61+	85.10	9.25	1.19	8.06	0.03	0.36	0.12	1.75	0.50
Pedon 6										
Ap	0.00 – 0.10	79.50	11.75	2.67	9.08	0.10	0.39	0.11	2.24	1.25
A1	0.10 – 0.26	81.30	10.75	2.31	8.44	0.07	0.48	0.09	2.10	1.12
A2	0.26 – 0.60	83.20	11.00	2.43	8.57	0.06	0.45	0.08	1.05	0.87
C	0.60	Weathered gneiss								
Pedon 7										
Ap	0.00 – 0.10	80.30	11.25	2.20	9.05	0.10	0.48	0.13	2.28	0.87
A1	0.10 – 0.38	84.90	9.50	1.64	7.86	0.09	0.54	0.08	1.75	0.87
A2	0.38 – 0.62	83.50	10.25	1.93	8.32	0.07	0.45	0.10	1.93	0.75
A3	0.62 – 0.91	83.80	8.75	1.44	7.31	0.07	0.39	0.11	1.58	0.62
C	0.91	Weathered gneiss								

Table 26 : Soil Classification

Pedon no.	Order	Suborder	Great group	Subgroup	Family	Tentative soil series.
1.	Inceptisols	Ustepts	Haplustepts	Vertic Haplustepts	Fine-loamy, smectitic, iso-hyperthermic, Vertic Haplustepts	Ramachandrapuram
2.	Entisols	Psamments	Ustipsamments	Typic Ustipsamments	Fine-loamy, siliceous, iso-hyperthermic, Typic Ustipsamments	Nennuru
3.	Inceptisols	Ustepts	Halpustepts	Typic Halpustepts	Fine-loamy, mixed, iso-hyperthermic, Typic Haplustepts	Sorakayalapalem
4.	Alfisols	Ustalfs	Haplustalfs	Typic Haplustalfs	Fine-loamy, kaolinitic, iso-hyperthermic, Typic Haplustalfs	Gangireddipalli
5.	Entisols	Fluvents	Ustifluvents	Typic Ustifluvents	Fine-loamy, siliceous, iso-hyperthermic, Typic Ustifluvents	Sanjeevarayapuram
6.	Entisols	Orthents	Ustorthents	Typic Ustorthents	Fine-loamy, siliceous, iso-hyperthermic, Typic Ustorthents	C.K.Palli
7.	Entisols	Orthents	Ustorthents	Typic Ustorthents	Fine-loamy, siliceous, iso-hyperthermic, Typic Ustorthents	Nethakuppam

Table 27: Land Capability classification of soils of Ramachandrapuram Mandal

Pedon no.	Tentative soil series	Soil characteristics										Land capability sub-class with limitations
		Surface texture	Solum depth (m)	Drainage	Slope (%)	Erosion	Organic carbon (%)	Graveliness	Stoniness	Salinity	Alkalinity	
1	Ramachandrapuram	scl	1.57	Imperfectly Drained	0-1	Nil	<1	-	-	-	-	IIs
2.	Nennuru	scl	1.83	Imperfectly Drained	0-1	Nil	<1	-	-	-	-	IIIs
3.	Sorakayalapalem	sil	2.08	Well drained	0-1	Nil	<1	-	-	-	-	IIs
4.	Gangireddipalli	scl	1.65	Well drained	1-3	Slight	<1	-	-	-	-	IIIs
5.	Sanjeevarayapuram	cl	1.61	Imperfectly drained	1-3	Slight	<1	-	-	-	-	IIIs
6.	C.K.Palli	scl	0.60	Moderately well drained	3-8	Moderate	<1	-	-	-	-	IVes
7.	Nethakuppam	scl	0.91	Moderately well drained	3-8	Moderate	<1	-	-	-	-	IVes

II : Good land
 III : Moderately good land
 IV : Fairly good land
 e : erosion
 s : soil / slope/ depth

Table 22: Range and mean of pH, EC, OC and available nutrients in surface soil samples of different revenue villages of Ramachandrapuram mandal

S. No.	Revenue Villages	Range and mean	pH (1:2.5)	EC (dSm ⁻¹)	Organic carbon (%)	N	P	K	S	Zn	Cu	Fe	Mn
						(kg ha ⁻¹)			(mg kg ⁻¹)				
1.	Ramachandrapuram	Range Mean	7.36 – 8.36 8.10	0.08 – 0.11 0.09	0.51 – 0.64 0.57	93.45– 167.64 125.32	15.28 – 23.96 19.48	225.00 – 310.00 276.88	3.42 – 6.55 5.12	0.23 – 0.86 0.54	0.64 – 1.21 0.89	2.49 – 5.82 4.04	6.22 – 11.63 8.80
2.	Nennuru	Range Mean	7.34 – 8.04 7.73	0.01 – 0.05 0.02	0.42 – 0.62 0.51	63.25 – 176.19 96.09	10.92 – 23.29 16.72	145.00 – 290.00 201.88	4.28 – 9.82 6.81	0.23 – 0.71 0.48	0.49 – 0.87 0.69	1.34 – 5.38 3.16	4.91 – 9.34 7.12
3.	C.K.Palli	Range Mean	6.39 – 7.41 7.07	0.01 – 0.05 0.02	0.46 – 0.53 0.49	63.11 – 152.71 97.49	10.34 – 21.28 17.41	135.00 – 310.00 229.38	3.69 – 7.82 5.90	0.34 – 0.79 0.57	0.43 – 0.89 0.65	1.09 – 3.21 2.30	4.28 – 8.72 7.12
4.	Sanjeevarayapuram	Range Mean	6.43 – 7.38 6.97	0.01 – 0.05 0.08	0.43 – 0.60 0.52	74.67 – 122.64 99.01	9.45 – 21.33 17.43	145.00 – 290.00 207.50	4.00 – 9.00 5.90	0.39 – 0.81 0.59	0.50 – 0.77 0.62	1.09 – 3.13 2.28	5.28 – 8.61 6.76
5.	Sorakayalapalem	Range Mean	7.37 – 8.23 7.91	0.01 – 0.10 0.05	0.53 – 0.71 0.62	98.26 – 178.13 149.09	10.67 – 23.26 18.42	190.00 – 305.00 252.50	4.38 – 9.00 6.37	0.39 – 0.82 0.61	0.39 – 0.71 0.51	2.13 – 4.26 3.26	5.49 – 9.30 7.71
6.	Gangireddipalli	Range Mean	7.19 – 8.11 7.58	0.02 – 0.08 0.04	0.55 – 0.71 0.63	82.64 – 171.86 113.39	9.73 – 21.56 17.50	155.00 – 290.00 224.00	4.00 – 9.82 6.70	0.43 – 0.86 0.66	0.38 – 0.59 0.47	1.98 – 4.59 3.26	8.28 – 12.33 9.94
7.	C.Ramapuram	Range Mean	7.21 – 8.03 7.58	0.04 – 0.08 0.05	0.42 – 0.64 0.53	54.93 – 102.26 82.96	14.28 – 21.91 18.42	190.00 – 310.00 270.00	5.00 – 8.00 6.59	0.21 – 0.82 0.48	0.21 – 1.21 0.66	1.28 – 4.02 3.05	6.34 – 12.61 9.59
8.	Nethakuppam	Range Mean	7.13 – 7.84 7.39	0.01 – 0.05 0.03	0.42 – 0.59 0.48	86.37-134.36 111.52	9.29 – 18.73 15.77	155.00 – 285.00 200.00	3.86 – 7.60 5.43	0.26 – 0.59 0.46	0.44 – 1.24 0.82	1.86 – 5.03 3.41	5.42 – 10.11 8.30
9.	Anupalli	Range Mean	7.34 – 8.29 7.93	0.04 – 0.11 0.08	0.54 – 0.70 0.61	74.61 – 138.21 108.50	15.24 – 23.19 19.45	175.00 – 310.00 256.25	4.03 – 9.70 6.74	0.34 – 1.04 0.75	0.49 – 1.24 0.81	1.82 – 4.71 3.25	5.23 – 11.39 8.68
10.	Kuppambadur	Range Mean	7.25 – 8.31 7.97	0.06 – 0.12 0.09	0.48 – 0.67 0.59	83.34 – 168.39 123.13	15.39 – 23.63 19.37	190.00 – 320.00 255.00	4.32 – 9.00 6.74	0.32 – 0.86 0.61	0.63 – 1.32 0.85	2.76 – 5.13 3.99	4.39 – 12.71 8.79
	Overall	Range Mean	6.39 – 8.36 7.62	0.01 – 0.12 0.06	0.01 – 0.12 0.06	54.93 – 102.26 110.65	9.29 -23.96 18.00	135.00 – 320.00 237.34	3.42 – 9.82 6.21	0.21-1.04 0.58	0.21 – 1.32 0.70	1.09 – 5.82 3.20	4.28 – 12.71 8.28

Table 17: Range and mean of molar concentration and molar ratios of the soils

Pedon No.	Range and mean	Molar concentrations				Molar ratios			
		SiO ₂	R ₂ O ₃	Al ₂ O ₃	Fe ₂ O ₃	SiO ₂ /R ₂ O ₃	SiO ₂ /Al ₂ O ₃	SiO ₂ /Fe ₂ O ₃	Al ₂ O ₃ /Fe ₂ O ₃
1.	Range Mean	1.33 – 1.39 1.35	0.083 – 0.119 0.106	0.070 – 0.100 0.089	0.013 – 0.020 0.018	11.18 – 16.74 13.02	13.30 – 19.86 15.59	67.50 – 106.92 79.58	4.40 – 5.38 5.09
2.	Range Mean	1.40 – 1.52 1.47	0.050 – 0.087 0.063	0.042 – 0.073 0.054	0.002 – 0.014 0.009	16.09 – 30.40 24.11	19.18-35.23 28.01	100.00 – 750.00 287.11	2.35 - 5.21 3.81
3.	Range Mean	1.29 – 1.32 1.31	0.092 – 0.123 0.113	0.079 – 0.103 0.093	0.013 – 0.025 0.020	10.48 – 14.35 11.72	12.62 – 16.70 14.19	51.60 – 101.54 69.00	3.74 – 6.08 4.83
4.	Range Mean	1.30 – 1.37 1.33	0.092 -0.142 0.123	0.076 – 0.121 0.103	0.016 – 0.028 0.020	9.15 – 14.89 11.06	10.40 – 18.03 13.06	46.42 – 85.63 67.50	4.07 – 6.05 5.12
5.	Range Mean	1.34 – 1.42 1.39	0.086 – 0.108 0.094	0.079 – 0.094 0.084	0.007 – 0.014 0.010	12.41 – 16.51 14.90	14.26 – 17.97 16.64	94.29 – 202.86 148.05	6.71 – 11.28 8.83
6.	Range Mean	1.32 – 1.38 1.35	0.096 – 0.107 0.101	0.082 – 0.090 0.085	0.014 – 0.017 0.015	12.34 – 14.06 13.45	14.67 – 16.46 15.85	77.64 – 96.43 88.69	5.30 – 5.86 5.59
7.	Range Mean	1.34 – 1.41 1.38	0.081 – 0.104 0.092	0.072 – 0.090 0.080	0.009 – 0.014 0.011	12.88 – 17.16 14.48	14.89 – 19.31 17.37	95.71 – 154.44 126.75	6.42 – 8.00 7.24

Table 23: Nutrient index and fertility status (N, P and K) in different revenue villages of Ramachandrapuram mandal

S.No.	Revenue villages	Number of samples	Available N		Available P		Available K	
			Nutrient index (NI)	Fertility status (FS)	Nutrient index (NI)	Fertility status (FS)	Nutrient index (NI)	Fertility status (FS)
1.	Ramachandrapuram	8	1.00	L	2.00	M	2.63	H
2.	Nennuru	8	1.00	L	2.00	M	2.13	M
3.	C.K.Palli	8	1.00	L	2.00	M	2.38	H
4.	Sanjeevarayapuram	8	1.00	L	1.88	M	2.25	M
5.	Sorakayalapalem	8	1.00	L	2.00	M	2.50	H
6.	Gangireddipalli	8	1.00	L	1.88	M	2.25	M
7.	C.Ramapuram	8	1.00	L	2.00	M	2.63	H
8.	Nethakuppam	8	1.00	L	1.88	M	2.13	M
9.	Anupalli	8	1.00	L	2.00	M	2.38	H
10.	Kuppambadur	8	1.00	L	2.00	M	2.38	H
Overall		80	1.00	L	1.96	M	2.37	H

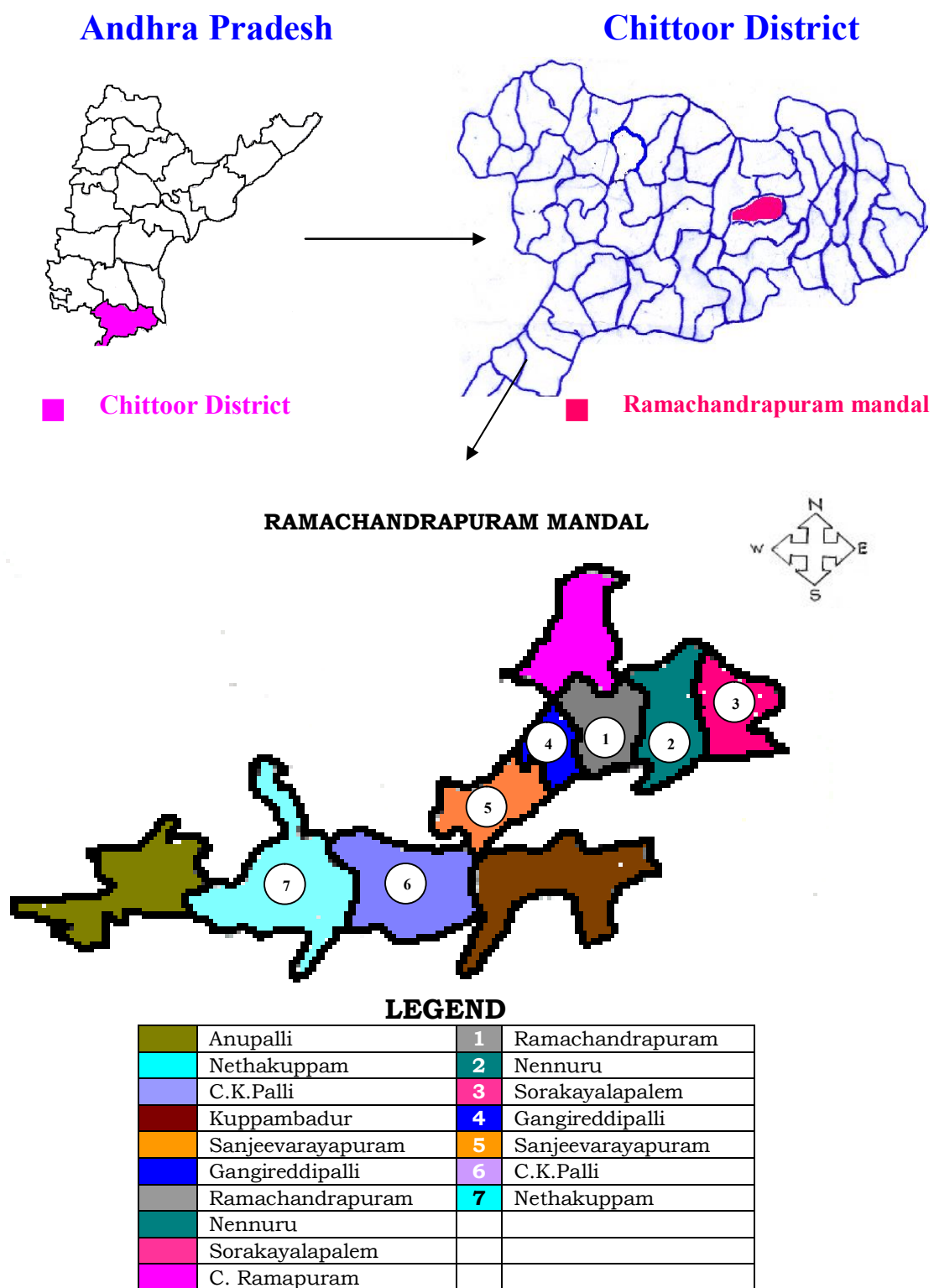


Fig. 1 : Location map of Ramachandrapuram mandal

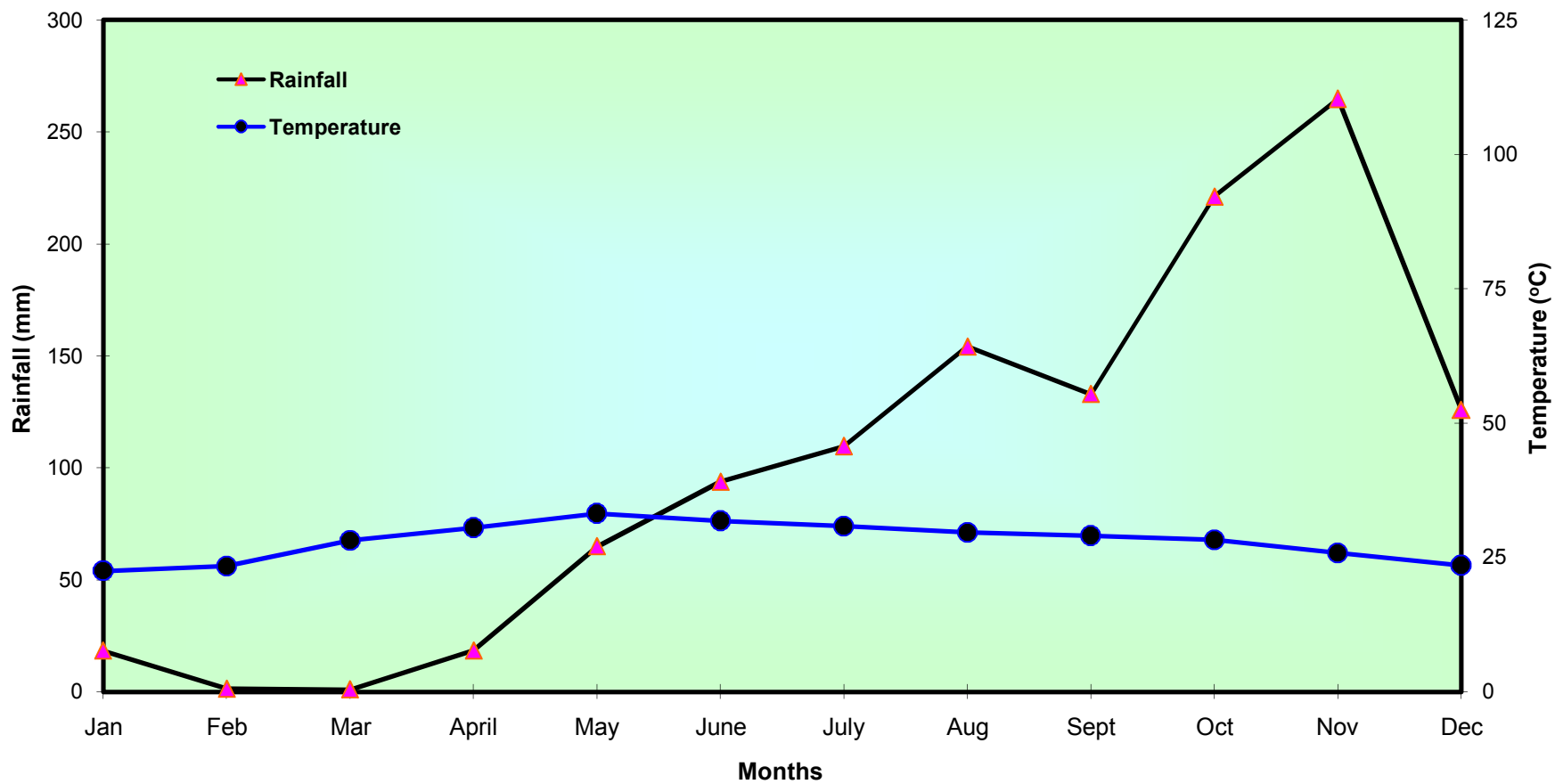


Fig. 2: Ombrothermic graph of study area (Ramachandrapuram mandal)

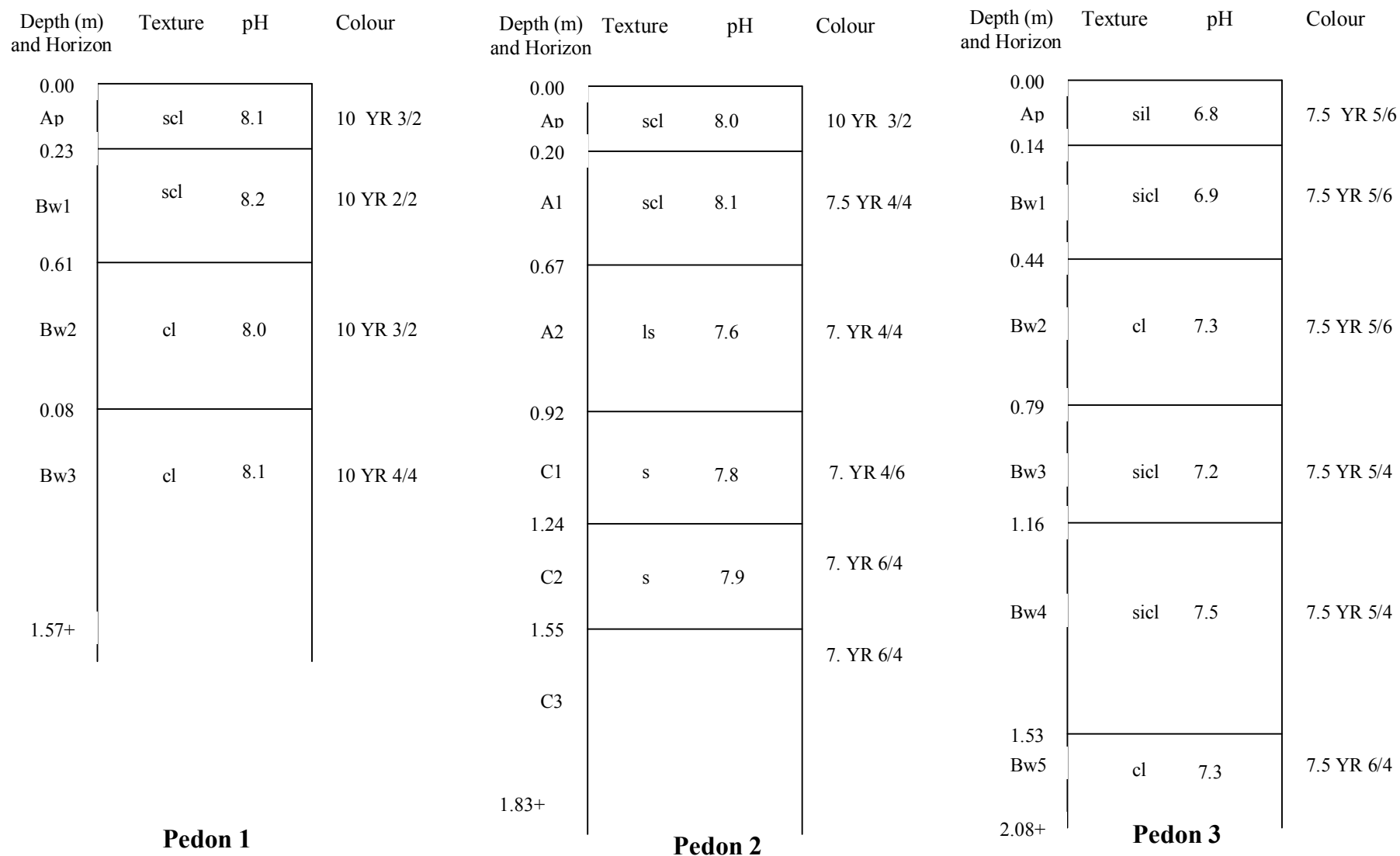


Fig. 3: Profile diagrams of pedons 1, 2 and 3

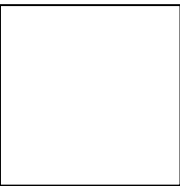
Depth (m) and Horizon	Texture	pH	Colour
0.00 Ap	scl	6.7	10 YR 4/3
0.17 E	sl	7.2	7.5 YR 5/6
0.36 Bt1	scl	7.0	7.5 YR 5/4
0.68 Bt2	cl	7.2	2.5 YR 4/2
1.21 Bt3	cl	7.0	2.5 YR 3/6
1.65+			7.5 YR 6/4

Pedon 4

Depth (m) and Horizon	Texture	pH	Colour
0.00 Ap	cl	7.6	10 YR 3/3
0.15 A1	l	8.2	10 YR 6/4
0.34 A2	scl	8.2	7.5 YR 4/4
0.74 A3	sl	8.1	7.5 YR 4/4
0.99 A4	sl	8.0	5 YR 5/6
1.14 A5	sl	7.9	
1.46 A6	sl	8.0	5 YR 4/6
1.61+			

Pedon 5

Fig. 4: Profile diagrams of pedons 4 and 5



Depth (m) and Horizon	Texture	pH	Colour
0.00 Ap	scl	7.1	10 YR 5/4
0.10 A1	scl	7.2	
0.26 A2	scl	7.2	2.5 YR 3/6
0.60 C			

Pedon 6

Depth (m) and Horizon	Texture	pH	Colour
0.00 Ap	scl	7.4	10 YR 3/2
0.10 A1	scl	7.1	10 YR 5/4
0.38 A2	scl	7.4	7.5 YR 4/6
0.62 A3	scl	7.5	7.5 YR 4/4
0.91 C			

Pedon 7

Fig. 5: Profile diagrams of pedons 6 and 7

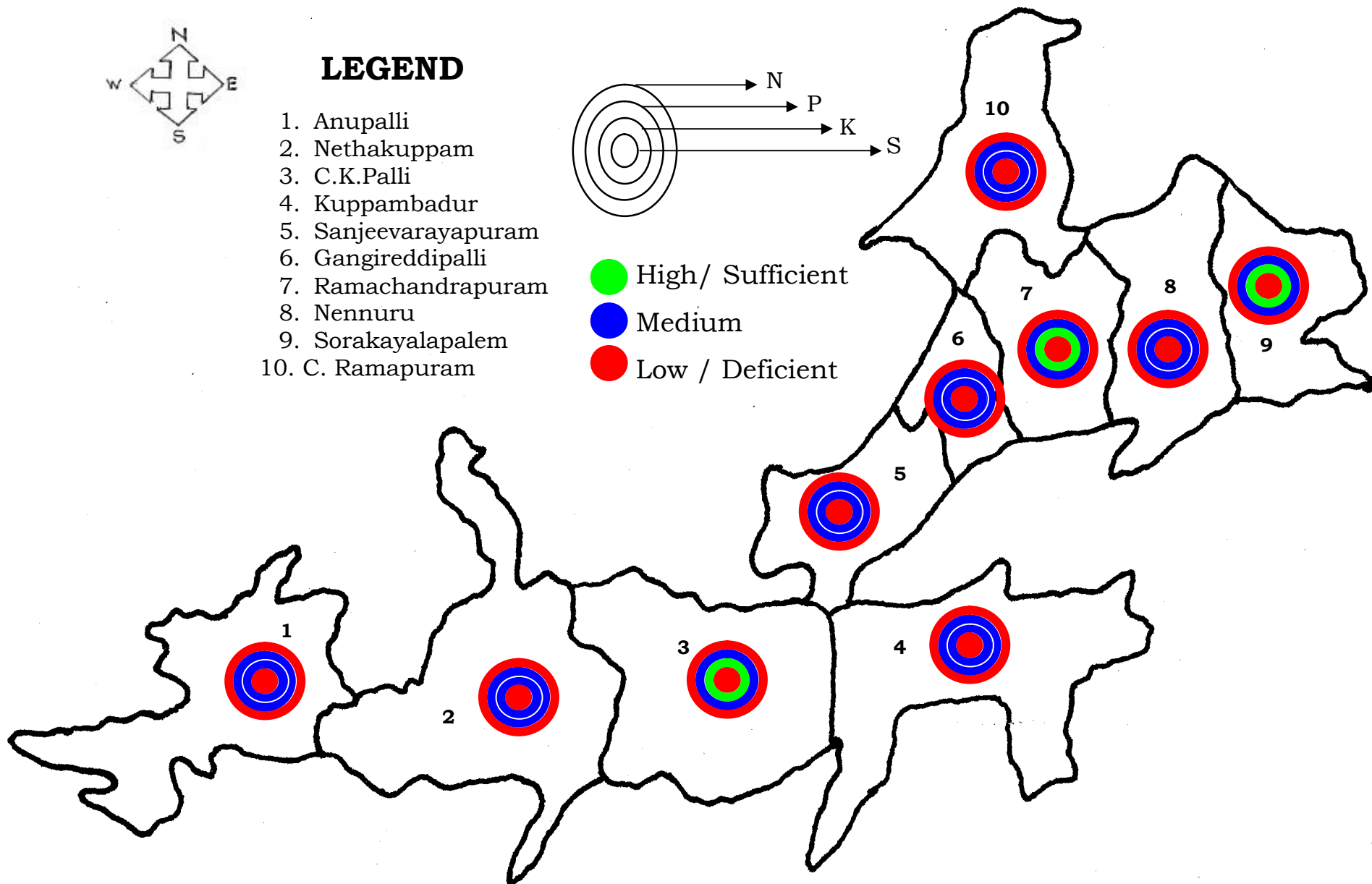


Fig.16: Fertility map of N, P, K and S in different revenue villages of Ramachandrapuram mandal

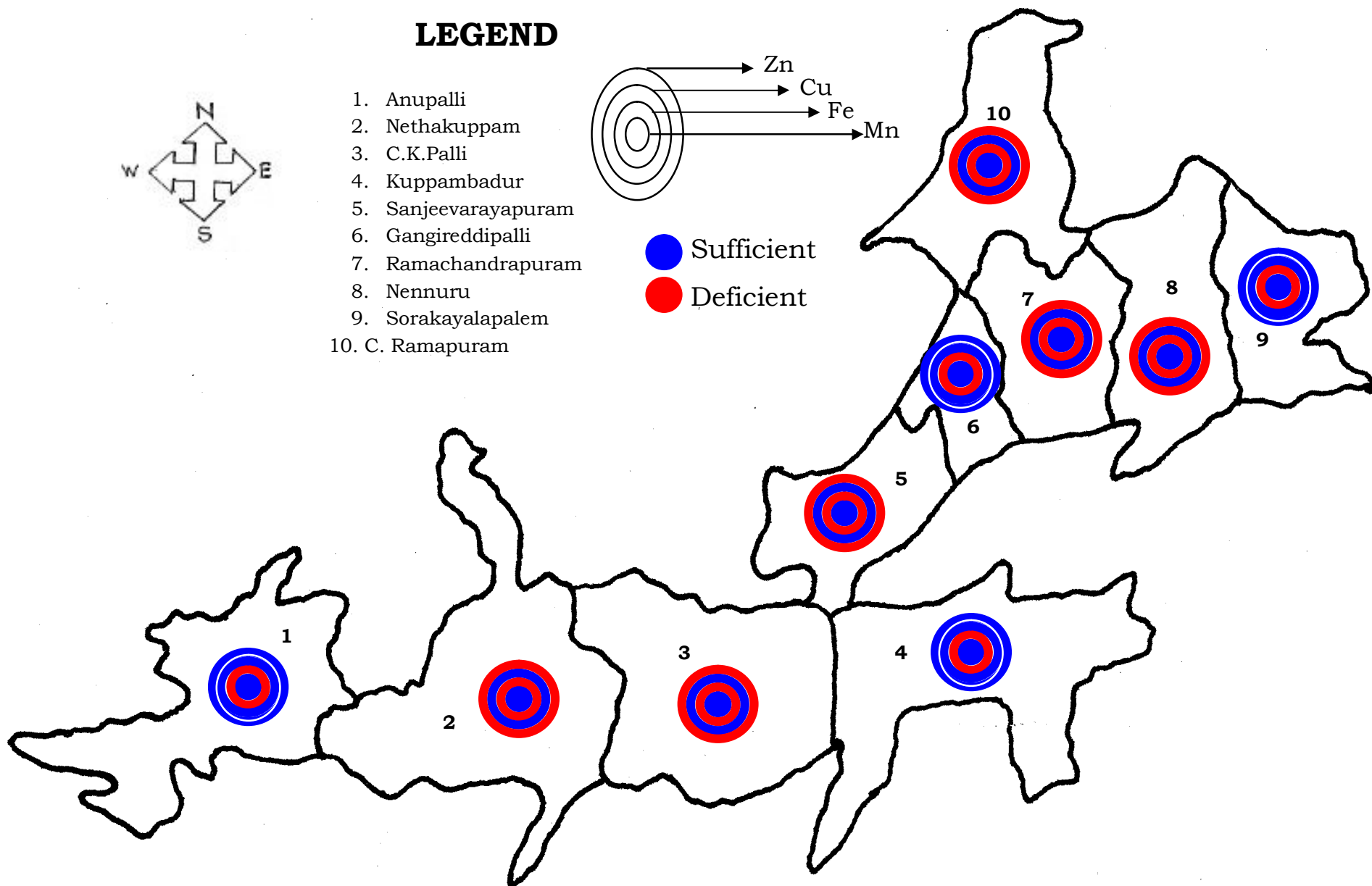


Fig.17: Fertility map of Zn, Cu, Fe and Mn in different revenue villages of Ramachandrapuram mandal

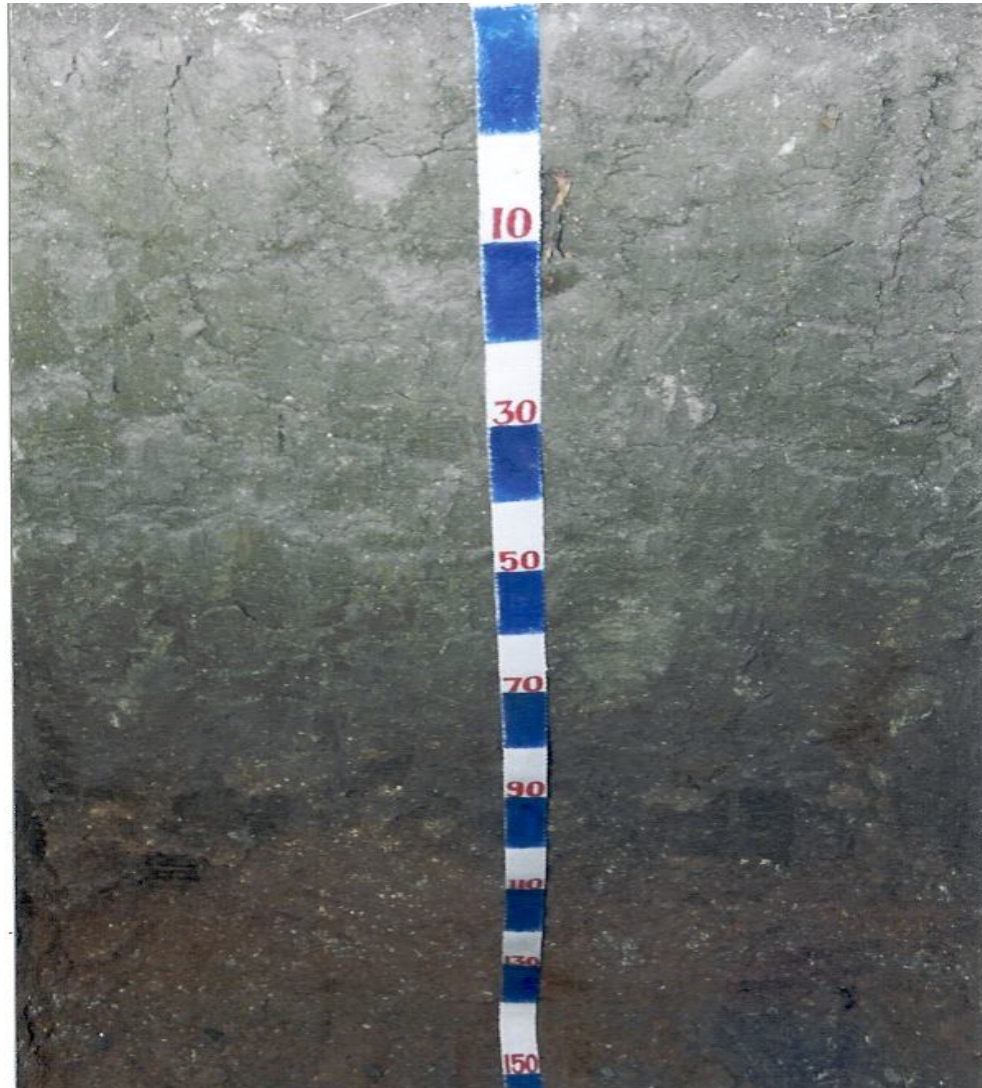


Plate 1 : Pedon 1



Plate 2: Pedon 2



Plate 3: Pedon 3

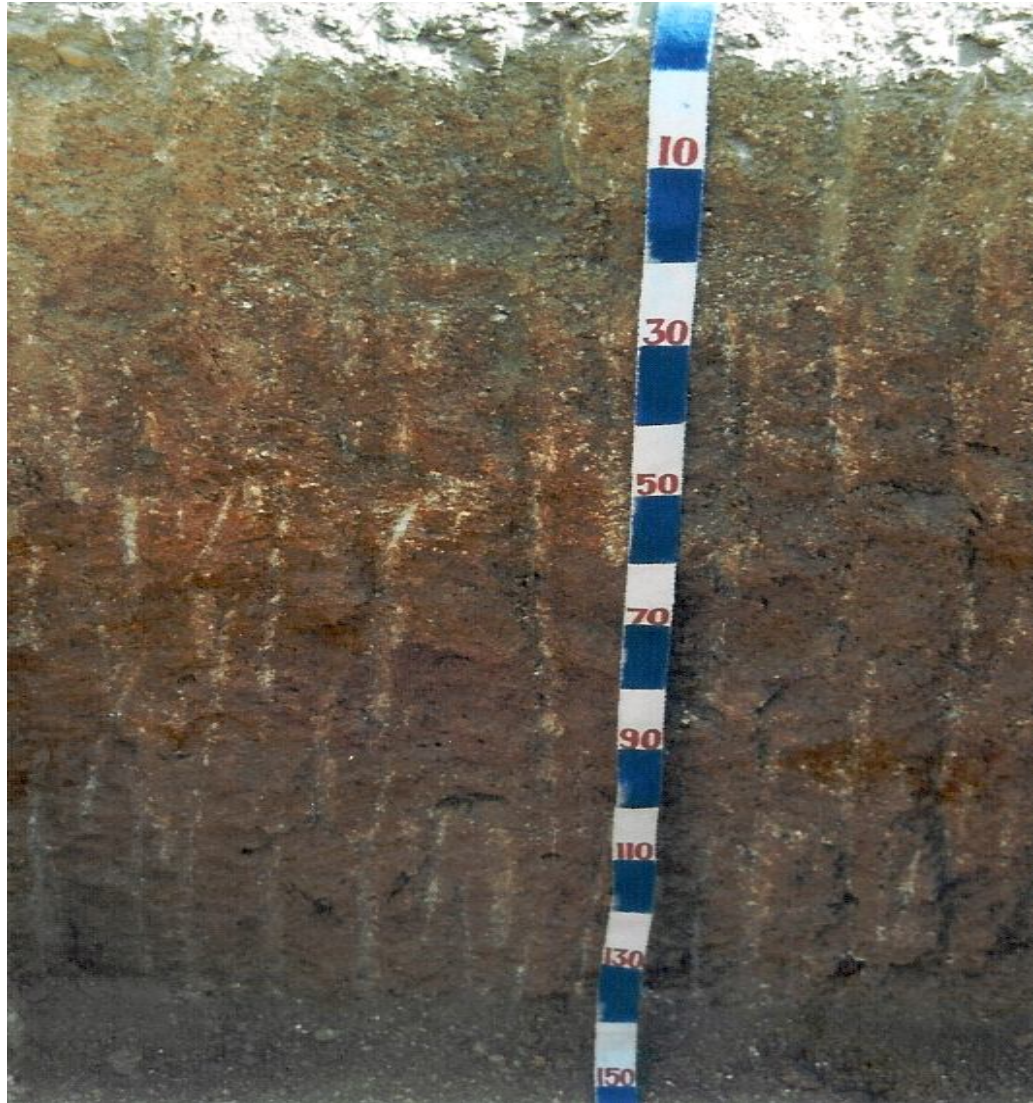


Plate 4: Pedon 4



Plate 5: Pedon 5



Plate 6: Pedon 6

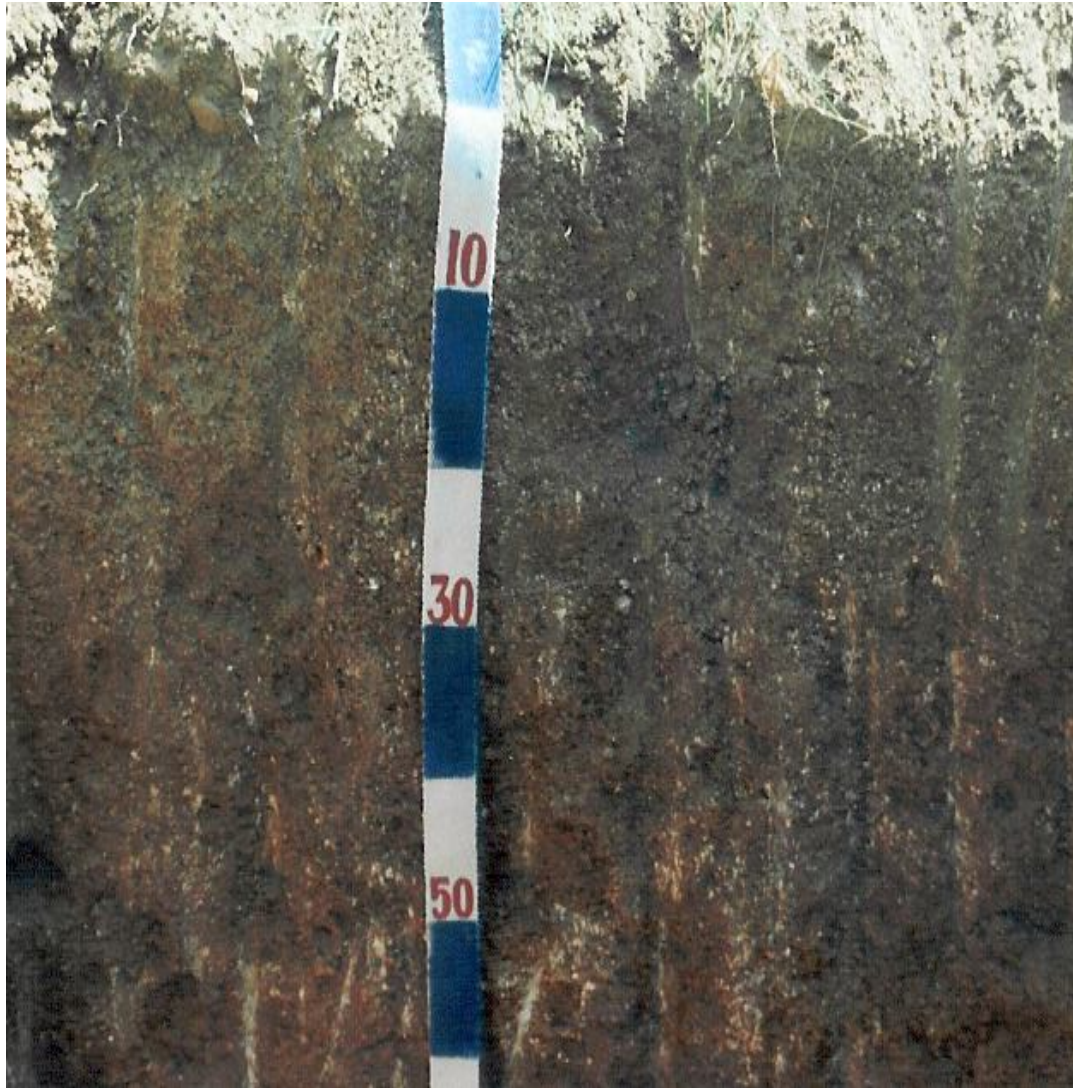


Plate 7: Pedon 7

CHAPTER - V

DISCUSSION

Soil is a vital natural resource on whose proper use depends the life supporting systems of a country and socio-economic development of its people. More than ever before, there is a renewed attention being given to soils, as knowledge and understanding of soils is either limited or is not being exploited for practical applications. Systematic study of morphology and taxonomy of soils will give the information on nature and type of soils, their problems, potentials, capabilities and their suitability for various uses. Hence, seven representative pedons from different parts of Ramachandrapuram mandal were examined for morphological features in the field and horizon-wise samples were analyzed in the laboratory for physical, physico-chemical and chemical characteristics.

Clay mineral analysis was also carried out to identify relative proportion of various clay minerals in the soil samples collected from control section of each pedon. Further, eighty surface soil samples were also collected from different revenue villages of the mandal and analysed for pH, EC, OC, available macronutrients (N,

P, K and S) and micronutrients (Zn, Cu, Fe and Mn) to know the fertility status of the Ramachandrapuram mandal.

Based on these characteristics, the soils were classified upto family level as per USDA soil taxonomy. Land capability classes and sub-classes were also assigned to these soils. Further, the results obtained on these parameters in the present study are discussed below.

5.1 PEDOGENESIS

5.1.1 Parent material

The parent materials are physically disintegrated or chemically decomposed mass (Soil Survey Staff, 1951) interacting with or acted upon by other environmental genetic factors over time and space developing soils.

The study area was comprised of mostly red and associated soils. All the soils of the study area were developed from granite-gneiss (Pedons 1, 3, 4, 5, 6 and 7) except pedon 2 which was developed from alluvium. According to Thangasamy *et al.* (2005), the red and associated soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh were developed from granite-gneiss and quartzite.

Satyavathi and Suryanarayan Reddy (2004) stated that the Inceptisols and Vertisols of Telengana region of Andhra Pradesh were originated from pink and grey granites, basalt, granite-gneiss and hornblende-schists. The red soils of Krishna district in Andhra Pradesh were developed from granite-gneiss parent material mixed with sandstone and quartz (Ramprakash and Seshagiri Rao, 2002).

5.1.2 Topography

Topography influences the climate and vegetation of an area and also affects the soil formation through slope and exposure. The soils of the study area occurred in nearly level sloping lands to gentle sloping lands. Pedons 1, 2 and 3 were developed on plain lands (0-1%), pedons 4 and 5 on very gentle slope (1-3%) and pedons 6 and 7 on gentle slope (3-8%). These results were in agreement with the findings of Tiwary *et al.*, (1989) who reported the occurrence of red soils in the uplands with steep slopes. The Inceptisols were formed on very gently to gently sloping uplands with a slope of 0-1 per cent (Seshagiri Rao *et al.*, 2004).

5.1.3 Climate

The parent material provide the bulk on which the climate act to produce soil. Climate is regarded as the active factor controlling the type and rate of soil formation. The importance of climate on soil formation was emphasized by Russian scientists Dokuchaev (1886), Sibirtsev (1901) and Glinka (1931). Soil genesis and development were influenced by soil temperature and moisture (Buol *et al.*, 1998).

The meteorological data for the past ten years (1995-2004) of the study area was confined to semi-arid monsoonic type of climate with distinct summer (April – June), rainy (July to November) and winter (December to March) seasons. The mean annual atmospheric air temperature was 28.04°C and the mean annual rainfall of the study area was 1205.96 mm of which 91.39 per cent was received during June to December. The overall climate of the study area is hot summer and mild winter. Thangasamy *et al.* (2005) reported that the Entisols, Inceptisols and Alfisols in Sivagiri micro-watershed area of Chittoor district in Andhra Pradesh were developed under semi-arid monsoonic climate with an annual rainfall of 1215 mm and mean annual air

temperature of 31.5°C. Ramprakash and Seshagiri Rao (2002) also stated that the red soils were confined to semi-arid monsoonic climate in Krishna district of Andhra Pradesh. Similar climate conditions were also observed by Dutta *et al.* (2001) in parts of South India.

Different types of soils *viz.*, Entisols, Inceptisols, Alfisols and Vertisols were formed under semi-arid monsoonic climate in Singarayakonda mandal of Prakasam district in Andhra Pradesh (Ramesh *et al.*, 2002). Similar findings were also reported by Vijay Kumar *et al.* (1994) in northern Telengana zone of Andhra Pradesh.

5.1.4 Time

Time is an important factor in the course of soil development which governs indirectly the activities and interactions of different factors of soil formation. Thus, it has dominant effects in changing the forms and mode of development of kinds of soils and their properties. All the soils do not age at the same rate. In general, aging is more rapid in warm and humid climate than in cold or hot arid climate. Parent material and relief also influences the age of the soil. The soils developed over granite-gneiss were

comparatively younger with higher nutrient reserves followed by soils developed on granite, charanokites and laterites (Lekha *et al.*, 1998) and the colour become redder with increasing age (Nayak *et al.*, 1999).

5.1.5 Vegetation

The nature of soil developed is governed to a great extent by the kind of vegetation as it influences soil evolution by production and addition of organic matter, translocation and accumulation of mineral substances.

The natural vegetation observed in the study area was *Parthenium hysterophorus*, *lantana camara*, *Acalypha indica*, *Lucas aspera*, *Tectona grandis*, *Cyprus rotundus* and *Cynadon dactylon*. Prasuna Rani *et al.* (1991), Gurumurthy *et al.* (1996) and Thangasamy *et al.* (2005) reported similar type of natural vegetation in Somasila project area, Giddalur mandal and Sivagiri micro-watershed in Chittoor district of Andhra Pradesh, respectively. Further, these lands were used for cultivation of seasonal crops like paddy, sugarcane, groundnut, jowar, maize, redgram, horsegram, various vegetable crops and orchard crops like mango and guava.

5.2 MORPHOLOGY OF THE TYPIFYING PEDONS

5.2.1 Depth

The soils of the study area were moderately deep to very deep. The depth of soils on gentle slope (pedons 6 and 7) was comparatively less than the soils on very gentle slope (pedons 4 and 5) and plains (pedons 1, 2 and 3). The depth of the pedon was the manifestation of topography (Singh and Mishra, 1996). Agbenin and Tiessen (1995) stated that solum thickness increased from upper to the lower slope in soils of north east Brazil. Ramprakash and Seshagiri Rao (2002) noticed the non-availability of adequate amount of water for prolonged period in the gently sloping soils associated with removal of finer particles and their deposition at lower pediplain have resulted in shallow soils in upper pediplain and deeper soils in lower pediplain. Similarly, in the present investigation also the pedons occurring in lower pediplain had deeper solum than the soils located on the upper pediplain.

5.2.2 Horizonation and horizon sequence

The pedons studied were characterised by AC, AB and AEB profiles. Horizonation was the main pedogenic process in Inceptisols and Alfisols. According to Simonson (1959) the basic processes involved in soil formation were gains such as addition of water, organic and mineral matter to the soil, losses of the above materials from the soil and transformation and / or translocation. Any one of the above processes might have taken place in these pedons, hence profile development occurred with AEB horizon.

Development of cambic horizon (Bw) was observed in pedons 2 and 3 as these pedons did not have rock structure, argillic, kandic, oxic or spodic horizons and had a regular decrease in the amount of organic carbon with depth. Development of cambic (Bw) horizon in Inceptisols of Trans-Yamuna river and in Etawah district of Uttar Pradesh was observed by Sidhu *et al.* (1998) and Verma *et al.* (2001), respectively.

The distribution of clay with depth in pedon 4 indicated the translocation of clay from A and E to B horizon and presence of films of oriented clay on ped surfaces in the field leads one to conclude that these soils have an argillic horizon (Bt). Sharma and Anil Kumar (2003) reported that the Alfisols and Inceptisols of upper Maul khad catchment in Himachal Pradesh were characterised by the presence of eluvial (Ap and AB) and illuvial (BA, Bw, Bt and BC) horizons of varying thickness. Dipak Sarkar *et al.* (2002) reported that marked increase in clay content in sub-surface in most of the soil might be due to illuviation of clay indicating the existence of argillic (Bt) horizon in Loktak catchment area of Manipur. Similar findings were also reported by Nanda *et al.* (1997) and Rudramurthy and Dasog (2001).

Further, the findings of the present investigation revealed that the pedons 2, 5, 6 and 7 did not exhibit any diagnostic sub-surface horizon, based on which they were characterised as Entisols. In Entisols, weak / no profile development was observed due to inert nature of parent material. The horizons recognized were only A and C horizons. Similar observations were made by Sidhu *et al.* (1994), Sidhu *et al.* (1999), Verma *et al.* (2001) and Arun Kumar *et al.* (2002).

5.2.3 Soil colour

Soil colour is one of the important basic properties which helps to identify the kinds of soils and recognize the succession of soil horizons / layers in soil profiles. The colour appears to be the function of chemical and mineralogical composition of the soil (Swarnam *et al.*, 2004).

Pedons 1, 2, 3 and 7 exhibited yellowish brown to very dark grayish brown colour with a hue of 7.5 YR to 10 YR, value in between 2 and 6 and chroma in the range of 1 to 6. This colour might be due to the reduction of iron caused by drainage conditions (Arun Prasad *et al.*, 1989; Chinchmalatpure *et al.*, 1998). In case of pedon 4, colour varied from dark red to dark brown with a hue varied from 2.5 to 10 YR, value of 3 to 5 and chroma of 2 to 6. Pedon 5 exhibited yellowish red to light yellowish brown colour with a hue varied from 5 to 10 YR, value of 3 to 6 and chroma in between 3 and 6. In pedon 6, the colour varied from dark red to yellowish brown with a hue in the range of 2.5 to 10 YR, value ranged from 3 to 5 and chroma between 4 and 6. These conditions indicated the release of iron oxides and their

occurrence in various hydrated forms due to difference in drainage of the soils (Walia and Rao, 1996). Similar findings were also reported by Thangasamy *et al.* (2005).

5.2.4 Structure

Structure designates the mode of arrangement of the particles. Structure determines the spatial distribution of solid material and voids. This distribution controls the fundamental physical properties of the soil. The structural variations in soils were useful to differentiate the horizon (Landay *et al.*, 1982). The study area had single grain, crumb, angular and sub-angular blocky structure. The blocky structures *i.e.* angular and sub-angular blocky were attributed to the presence of higher quantities of clay fractions (Murthy *et al.*, 1994; Giri Prakash, 1997; Kadao *et al.*, 2003; Sharma *et al.*, 2004). Crumb structure in the pedons 2 and 3 might be due to continuous addition of organic matter through vegetation. The single grain structure of the soils might be due to inert nature of parent materials. The structure of the Inceptisols of Chandauli district in Uttar Pradesh was sub-angular blocky which was a reflection of their sandy loam to sandy clay loam texture (Singh and Agrawal, 2003). The Entisols of flood

plains of Punjab are lacking structural development in control sections (Sidhu *et al.*, 1994). These observations were found to be similar with those Krishnan *et al.* (2004) in Entisols of Lakshadweep islands, with those of Arun Kumar *et al.* (2002) in Entisols of Tamil Nadu and Sehgal (1996) in Entisols of Rajasthan.

5.2.5 Texture

The texture of surface horizons varied from sandy clay loam to clay loam whereas in sub-surface horizons it varied from sandy to clay loam. These variations were caused by topographic position, nature of parent material, *in situ* weathering, translocation of clay and age of soils. The variations in texture of the soils was also mainly due to the differences in composition of parent materials (Nayak *et al.*, 2002). Krishnan *et al.* (2004) stated that the Entisols of Lakshadweep islands were light textured, predominantly, sandy or loamy sand and occasionally sandy loam in texture. Similar results were also made by Walia and Rao (1997), Giri Prakash (1997) and Thangasamy *et al.* (2005).

5.2.6 Consistence

Consistence indicates the cohesion and resistance to pressure of the structural units. Consistence varies with texture and type and stability of the structure.

The consistence of these soils varied from soft to very hard, loose to very firm and non-sticky and non-plastic to very sticky and very plastic in dry, moist and wet conditions, respectively. This qualitative physical behaviour of soils as influenced by dry, moist and wet conditions was not only due to the textural make up but also due to the type of clay minerals present in these soils. Presence of loose, friable and non-sticky and non-plastic or slightly sticky and slightly plastic consistence might be due to negligible or very small amount of expanding clay minerals. Similar findings were also reported by Thangasamy *et al.* (2004) in the soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh. Sharma and Anil Kumar (2003) reported that the dry consistence in sandy loam to loamy soils varied from soft to hard whereas loamy sand to silty clay loam soils was loose to extremely hard in Maul khad catchment of Himachal Pradesh. Similar findings were also made by Sharma *et al.* (2004) in soils of Neogal watershed in North-West Himalayas and Marathe *et al.* (2003) in Typic Ustorthents.

Sticky and plastic to very sticky and very plastic, firm to very firm and slightly hard to very hard consistence in wet, moist and dry conditions, respectively might be due to high clay content of the soils. Similar observations were also made by Dipak Sarkar *et al.* (2001) in soils of lower outlier of Chhotanagpur plateau.

5.2.8 Cracks

Cracks of 3 to 5 mm wide which extended to a depth of 35 cm were noticed in pedon 1 alone. These cracks were evident in summer months. Development of cracks might be due to the presence of shrinking and swelling type of clay minerals. Further, the mineralogical study carried out in the present investigation confirmed the dominance of smectite clay mineral in this pedon, which might be responsible for the development of cracks. Thangasamy *et al.* (2005) reported 3 to 7 mm wide cracks in Vertic Haplustepts of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh. Similar findings were also made by Sharma *et al.* (2001) in soils of Kathiawar region of Gujarat and by Marathe *et al.* (2003) in Vertic Haplustepts of mandarin orchards in Nagpur.

5.2.9 Slickensides

Pedon 1 showed weak indistinct slickensides in deeper layers. The formation of slickensides might be due to the presence of high amount of expanding minerals, alternate wetting and drying cycles and soil depth more than 0.5 m (Soil Survey Staff, 1998). Thangasamy *et al.* (2005) observed weak indistinct slickensides in lower horizons of Vertic Haplustepts in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh. Sharma *et al.* (1997) observed slickensides in subsurface horizons of Inceptisols having more than 30 per cent clay in North-West India. These findings were further supported by the dominance of smectite (69.40%) clay mineral in this pedon.

5.3 PHYSICAL PROPERTIES

5.3.1 Particle size analysis

5.3.1.1 Clay

The clay content of different pedons ranged from 4.33 to 35.64 per cent. The increase in clay content in Bt horizon of pedon 4 could be attributed to vertical migration or translocation of clay whereas the enrichment of clay in Bw horizon of pedons 1 and 3

was primarily due to *in situ* weathering of parent material. Sharma *et al.* (2004) observed an increase in clay content in sub-surface horizons as compared to surface horizons in soils of Neogal watershed in North-West Himalayas. Similar observations were also made by Walia and Rao (1996) in soils of Bundelkhand region of Uttar Pradesh and by Nayak *et al.* (2002) in soils of Central Research Station (OUAT), Bhubaneswar. More or less decrease of clay content with depth was noticed in pedons 2, 5 and 7. This might be due to variability in weathering of different horizons. Giri Prakash (1997) has also reported an irregular decrease of clay content with depth in soils of Gudiyatham taluk in Tamil Nadu.

5.3.1.2 Silt

Silt content ranged from 4.97 to 56.53 per cent. All the pedons except pedons 2 and 6 exhibited an irregular trend with depth. This might be due to variation in weathering of parent material or *in situ* formation. These results were in agreement with the findings of Naidu (2002), who noticed an irregular trend in silt content with depth in sugarcane growing soils of Karnataka. Similar results were also reported by Arun Kumar *et al.* (2002). Further, pedons 2 and 6 showed a decreasing trend with depth.

5.3.1.3 Sand

Sand content in the pedons varied from 16.81 to 89.82 per cent. The sand content increased with depth in pedons 2, 5 and 6. This could be due to progressive decrease in the deposition of sand by the river in due course of time. Similar increase in the sand content with depth in Typic Ustipsamments located on active flood plain in Etawah district of Uttar Pradesh was also reported by Verma *et al.* (2001).

Pedons 1 and 4 showed a decreasing trend with depth which might be due to the detachment of finer particles from the soil body, which were translocated to deeper layers by percolating water and surface depletion (Buol *et al.*, 1998). Similar findings were also reported by Sharma *et al.* (2001) in Kathiwar region of Gujarat.

5.3.1.4 Ratios of soil particles

The sand – silt ratio increased with depth in pedons 2 and 6 due to deposition of alluvial materials. The wider sand – silt ratio in soils of Brahmaputra valley of Assam indicated lithological

discontinuity due to deposition of alluvial materials in fluvial cycles (Gangopadhyay *et al.*, 1998).

5.3.2 Physical constants

5.3.2.1 Soil density

Bulk density of different pedons varied from 1.45 to 1.66 Mg m⁻³. Similar results were obtained by Ramprakash and Seshagiri Rao (2002), Sharma and Anil Kumar (2003) and Swarnam *et al.* (2004) in red soils of Krishna district of Andhra Pradesh, Maul khad catchment of Himachal Pradesh and in the Entisols and Inceptisols of Shahibi basin in Haryana and Delhi respectively. Kadao *et al.* (2003) reported that the bulk density values in banana growing soils of Wardha district of Maharashtra ranged from 1.49 to 1.79 Mg m⁻³ in Inceptisols. All the pedons had shown an increasing trend with depth. This might be due to more compaction of finer particles in deeper layers caused by over head weight of the surface soil.

Low bulk density of surface soils would be attributed to higher organic matter content. This is evident from the significant negative correlation ($r=-0.770$) with organic carbon.

Particle density of different pedons ranged from 2.39 to 2.65 Mg m⁻³. All the pedons did not show any specific trend with depth. Since there is no significant variation in textural components and more or less uniform values were recorded in all the pedons. Gurumurthy *et al.* (1996) observed more or less uniform particle density in the soils of Giddalur mandal in Prakasam district of Andhra Pradesh.

5.3.2.2 Water holding capacity

Water holding capacity of different pedons ranged from 19.96 to 47.81 per cent. These differences were due to variation in the depth, clay and organic carbon content of the pedons. These results were coincided with those of Singh *et al.* (1999) in soils of Ramganga catchment in Uttar Pradesh.

The water holding capacity was increased with depth in pedon 1. Increase in clay content with depth might have imparted greater water holding capacity in the deeper layers which was confirmed by a significant positive correlation (0.795) between water holding capacity and clay. Similar increase in water holding

capacity with depth in soils of Krishna district, Andhra Pradesh was reported by Ramprakash and Seshagiri Rao (2002) and also in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh by Thangasamy *et al.* (2005).

Surface soil in pedon 7 had the highest water holding capacity than sub-surface horizons which might be due to presence of higher clay and organic matter content in the surface soil. Water holding capacity was very less in sandy soils due to high sand and less clay content as evident by negative correlation ($r=-0.693$) between water holding capacity and sand content. Singa Rao and Prabhu Prasadini (1998) also observed similar type of negative correlation between water holding capacity and sand.

Except in pedons 1 and 7, the water holding capacity of the remaining pedons did not show any specific trend with depth. The irregular trend was due to the illuviation and eluviation of finer fractions in different horizons.

5.3.2.3 Pore space

The pore space of all the pedons ranged from 20.51 to 57.98 per cent. Except pedons 1 and 3, all the pedons exhibited a more or less decreasing trend with depth, which could be attributed to more compaction in deeper layers. This corroborates the study of Gurumurthy *et al.* (1996). Walia and Rao (1996) stated that the decrease in pore space with depth might be due to increase in coarse fraction or coarse fragments in Inceptisols and Entisols and filling up of pores by eluvial materials in Alfisols.

5.3.2.4 Volume expansion

The values of volume expansion were found to be in the range of 2.91 to 26.32 per cent. The volume expansion had significant positive correlation with clay ($r=0.779$) and clay + silt ($r=0.670$) content. The volume expansion was indicating the presence of shrinking and swelling type of clay minerals. Sandy soils have very low volume expansion. Increase in volume expansion with increase in clay content was reported by Gurumurthy *et al.* (1996) in soils of Giddalur mandal in Andhra Pradesh.

5.3.2.5 Loss on ignition (LOI)

These values were ranged from 2.10 to 6.85 per cent. This loss in weight on ignition was attributed to loss of organic matter, crystal lattice water and CaCO_3 content. More the clay content, more was the loss of weight due to loss of crystal lattice water held by the clay. The present study revealed positive correlation between loss on ignition and clay content ($r=0.658$). Khan *et al.* (1998) also observed similar type of positive correlation between LOI and clay. Sand possessed negative correlation ($r=-0.547$) with LOI. Similarly, Sharma *et al.* (1996) noticed the fact that loss on ignition followed the same distribution pattern as that of clay content.

5.4 PHYSICO-CHEMICAL PROPERTIES OF THE SOILS

5.4.1 Soil reaction

All the pedons studied were slightly acidic to moderately alkaline in reaction. Similar results were obtained by Arun Kumar *et al.* (2002) and Thangasamy *et al.* (2005). This wide variation in pH is attributed to the nature of the parent material, leaching, presence of calcium carbonate and exchangeable sodium. Except in pedon 2, all the pedons showed more or less increasing trend

with depth. This might be due to the release of organic acids during decomposition of organic matter and these acids might have brought down the pH in the surface soils. Vadivelu and Bandyopadhyay (1997) observed similar results in soils of Minicoy islands in Lakshadweep.

In pedon 2, pH values are comparatively high in surface soils than in sub-surface soils. This might be due to accumulation of more exchangeable bases and CaCO_3 in surface horizons. Similar results were also made by Walia and Rao (1996) in Bundelkhand region of Uttar Pradesh.

The KCl – pH values are lower than the water pH values indicating the existence of net negative charge on colloidal particles. Dipak Sarkar *et al.* (2002) observed lesser KCl-pH values than H_2O – pH values in Loktak catchment of Manipur. Similar results were also observed by Mishra and Ghosh (1995) and Dutta *et al.* (2001).

5.4.2 Electrical conductivity

All the pedons had shown very low electrical conductivity values varying from 0.01 to 0.18 dSm⁻¹ indicating non-saline nature of the soil. Pillai and Natarajan (2004) reported similar low electrical conductivity values indicating the non-saline character in the soils of Garakahalli watershed. These results were coincided with those of Thangasamy *et al.* (2005), Sharma *et al.* (1997) and Walia and Rao (1996) in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh, in Inceptisols of North-West India and in soils of Bundelkhand region of Uttar Pradesh, respectively.

5.4.3 Organic carbon

The organic carbon content of these soils was found to vary between 0.12 and 0.77 per cent *i.e.* low to medium. The organic carbon content decreased with depth in all the pedons except in pedons 4 and 5 where an irregular decrease with depth was observed. This is attributed to the addition of plant residues and farm yard manure to surface horizons which had resulted in higher organic carbon content in surface horizons than in the lower horizons. This observation is in accordance with results of

Ramprakash and Seshagiri Rao (2002) and Dipak Sarkar *et al.* (2001) in soils of Krishna district, Andhra Pradesh and in soils of lower outlier in Chhotanagpur plateau, respectively. The reason for the low organic matter content in the soils might be attributed to the prevalence of tropical condition, where the degradation of organic matter occurs at a faster rate coupled with low vegetation cover, thereby leaving less organic carbon in the soils. Similar observations were also made by Nayak *et al.* (2002) in soils of Central Research Station (OUAT), Bhubaneswar.

5.4.4 Cation exchange capacity

The cation exchange capacity in all the pedons estimated by ammonium acetate extract varied from 6.65 to 27.60 cmol(p+) kg^{-1} soil. The CEC values of the pedons 1, 3, 4 and 6 were more or less increased with depth. However, the maximum CEC was observed in the horizons of pedons where illuvial accumulation of clay had taken place. Further, the CEC values showed more or less decreasing trend with depth in pedons 2, 5 and 7 where the CEC corresponds to clay content in the horizons. Similar results were also reported by Rudramurthy and Dasog (2001) and Thangasamy *et al.* (2005). A positive correlation ($r=0.487$) between clay content

and CEC suggests that clay is the contributor of CEC in the soils. Similar findings were also observed by Arun Kumar *et al.* (2002), who reported a significant positive correlation between CEC and clay content and suggested that the clay is the contributor to the CEC in the soils of lower Palar – Manimuthar watershed of Tamil Nadu. These results were in agreement with the results of Sharma *et al.* (1997).

5.4.5 Calcium carbonate (CaCO_3)

The CaCO_3 content of these soils ranged from 0.45 to 1.83 per cent. High CaCO_3 content was noticed in pedon 1. This might be due to high clay content which led to impeded leaching, consequently accumulation of CaCO_3 in lower horizon. Similar results were reported by Ramprakash and Seshagiri Rao (2002) in soils of Krishna district, Andhra Pradesh.

5.4.6 Base saturation

The base saturation was found to be varied from 60.13 to 98.29 per cent. All the pedons were more base saturated. The variation in per cent base saturation indicates the degree of leaching.

5.4.7 Exchangeable bases

The exchangeable bases in all the pedons were in the order of $\text{Ca}^{2+} > \text{Mg}^{2+} > \text{Na}^+ > \text{K}^+$ on the exchange complex. The exchangeable calcium was found to be the dominant cation followed by magnesium on the exchange complex. From the distribution of Ca^{2+} and Mg^{2+} , it is evident that Ca^{2+} shows the strongest relationship with all the species, comparing these ions (Ca^{2+} , Mg^{2+} , K^+ and Na^+) it was clear that Mg^{2+} was present in low amounts than Ca^{2+} because of its higher mobility, earlier removal than the latter. Presence of basic cations in decreasing order Ca, Mg, Na and K reflects the decreasing energy of adsorption by the complex and accordingly the increasing mobility of ions against the leaching environment. Calcium dominates in the prevailing semi-arid weathering environment and consequently occupied the major position on the exchange complex (Sharma *et al.*, 1996). The basic cation content was low in all the pedons which might be due to less clay and high silica content. Similar observations were earlier made by Arun Kumar *et al.* (2002) and Dipak Sarkar *et al.* (2001).

5.5 CHEMICAL COMPOSITION OF THE SOILS

5.5.1 Silica

Silica content in different pedons ranged from 78.20 to 91.10 per cent. These variations in silica were mainly associated with the variations in chemical composition of parent material and also relative amount of sand fraction. Pedons 3 and 4 exhibited more or less decreasing trend with depth due to high clay content and low sand content in deeper layers. Similar results were also reported by Ramprakash and Seshagiri Rao (2002) in soils of Krishna district, Andhra Pradesh. Decreasing trend with depth could be due to removal of weatherable products by leaching, leaving SiO_2 in surface under existing climate of the area and intimate association of SiO_2 with coarser fraction of the soil (Singh *et al.*, 1993).

All the pedons except pedons 3 and 4 had more silica content and exhibited increasing trend with depth due to more sand content in deeper layers. Similar increase in sand content with depth in soils located on active flood plain was noticed in

Etawah district of Uttar Pradesh (Verma *et al.*, 2001). This was confirmed by significant positive correlation ($r=0.880$) between sand and silica contents.

5.5.2 Sesquioxides

Sesquioxides (R_2O_3) content of the pedons varied from 5.25 to 16.25 per cent. These variations in R_2O_3 content might be due to the kind of parent material from which the soils derived. More or less increasing trend with increasing depth was observed in pedons 1, 3 and 4 due to increasing clay content with depth. A significant negative correlation ($r=-0.752$) between sand and sesquioxides content whereas a significant positive correlation ($r=0.587$) between clay and sesquioxides content was observed. Sesquioxides values showed an increasing trend with increase in clay content and a positive correlation between clay and sesquioxides (Gurumurthy *et al.*, 1996). Similar results were earlier reported by Subbaiah and Manickam (1992) in soils of Andhra Pradesh.

5.5.3 Aluminum oxide

Alumina (Al_2O_3) content varied from 4.29 to 12.29 per cent with a difference of 8.00 units. Contribution of the alumina to the sesquioxide content was major hence, the pattern of distribution of sesquioxides was similar to that of alumina. The results were in corroboration with the findings of Ramalakshmi *et al.* (2001). Sandy soils had very less alumina content because they are major contributors of silica.

5.5.4 Iron oxide

The iron oxide content varied from 0.39 to 4.53 per cent with a difference of 3.14 units and this variation could be due to the variation in chemical composition and mineralogical composition of the parent materials. Pedons 2 and 7 showed a more or less decreasing trend, pedon 4 exhibited an irregular increasing trend and the remaining pedons did not exhibit any particular trend with depth. The distribution of Fe_2O_3 within the profile is related to the degree of weathering and nature of parent material (Walia and Rao, 1996). Similar results were reported by Subbaiah and Manickam (1989) in soils of Andhra Pradesh.

5.5.5 Molar ratios of chemical constituents of soils

The ratios of $\text{SiO}_2/\text{R}_2\text{O}_3$, $\text{SiO}_2/\text{Al}_2\text{O}_3$, $\text{SiO}_2/\text{Fe}_2\text{O}_3$ and $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ were higher in all the soils which might be due to siliceous nature of the parent material and earlier stage of weathering. Similar results were also reported by Ramprakash and Seshagiri Rao (2002) in red soils of Krishna district, Andhra Pradesh.

$\text{SiO}_2/\text{R}_2\text{O}_3$ and $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratios were decreased with depth in pedons 1, 3 and 4 while an increasing trend with depth was noticed in the remaining pedons. Pedons 1, 3 and 4 showed a decreasing trend of $\text{SiO}_2/\text{Fe}_2\text{O}_3$ with depth and remaining pedons exhibited a more less increasing trend with depth. Further, a decreasing trend of $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ with depth in pedons 1, 2 and 3 was observed while other pedons showed an irregular increase with depth.

The decreasing trend of $\text{SiO}_2/\text{R}_2\text{O}_3$ and $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratios with depth might be due to decrease in sand content and increase in clay content. This was in conformity with the studies of Mahesh Babu (1992) and Anitha (1996). Similar findings were also reported by Ratnam *et al.* (2000) in the soils of Kakumanu mandal of Guntur district, Andhra Pradesh.

The irregular trend of $\text{SiO}_2 / \text{R}_2\text{O}_3$, $\text{SiO}_2 / \text{Al}_2\text{O}_3$ and $\text{Al}_2\text{O}_3 / \text{Fe}_2\text{O}_3$ could be attributed to the heterogeneous nature of parent materials (Khan *et al.*, 1997). These findings were in conformity with the findings of Walia and Rao (1996) in red soils of Uttar Pradesh. Wide molar ratios of these soils revealed that silication was the dominant process operating in these soils. Slight variations within the pedons could be due to variation in chemical composition of parent material. These results were in good agreement with those of Tiwary and Mishra (1992).

5.6 NUTRIENT STATUS

5.6.1 Macronutrients

5.6.1.1 Total nitrogen

The total nitrogen content of the pedons varied from 98.00 to 770.00 mg kg⁻¹ soil and all the pedons except pedons 3 and 4 exhibited a decreasing trend with depth, which might be due to decreasing trend of organic carbon with depth, as evident from significant positive correlation of total nitrogen ($r=0.987$) with organic carbon. The C:N ratio of these soils is low, this could be attributed to rapid mineralization of litter, as these soils possess good soil moisture condition for microbial activity. Similar views were expressed by Ramprakash and Seshagiri Rao (2002) in red soils of Krishna district, Andhra Pradesh.

5.6.1.2 Total phosphorus

The distribution of total phosphorus among the horizons of each pedon was found to be ranged from 75.00 to 487.50 mg kg⁻¹ soil. In general, a decrease in total phosphorus content with increase in depth was noticed. High organic matter in the surface and addition of phosphatic fertilizers to soils were the causes for high phosphorus content in the surface soils. Further, total phosphorus content showed a significant positive correlation ($r=0.798$) with organic carbon. These observations were in accordance with the findings of Ramalakshmi and Seshagiri Rao (2000).

5.6.1.3 Total potassium

The total potassium content varied from 1000 to 4500 mg kg⁻¹ soil. Relatively higher total potassium values were recorded in pedon 7. Further, all the pedons did not show any particular trend with change in depth. In general, high total potassium content in different horizons of pedons was due to the existence of semi-arid climate (Mehta *et al.*, 1996). Wide variation in potassium content

might be due to the nature of parent material (variation in potassium bearing minerals). Similar observation was earlier made by Prasuna Rani *et al.* (1992) in red soils of Nellore district in Andhra Pradesh.

5.6.1.4 Total sulphur

The total sulphur content in the horizons of all the pedons varied from 85.00 to 375.00 mg kg⁻¹ soil. The surface horizons of all the pedons recorded higher total sulphur content than sub-surface horizons, which might be due to the fact that most of the soil sulphur was primarily in the organic form. Further, with increasing depth the organic carbon content was decreased and total sulphur also exhibited similar trend in all the pedons. In general, all the pedons recorded low total sulphur content which might be due to negligible use of organic manures and sulphur containing fertilizers and pesticides. A significant positive correlation ($r=0.910$) between organic matter and total sulphur was observed. Similar results were also reported by Bhatnagar *et al.* (2003) in soils of Shivpuri district in Madhya Pradesh.

5.6.2 Micronutrients

5.6.2.1 Total zinc

Total zinc content varied from 9.50 to 30.50 mg kg⁻¹ soil. Parent materials and nature of associated minerals were the predominant determinants of the total micronutrients in soils (Murthy *et al.*, 1997). Similar results were also reported by Samanta *et al.* (2002) in soils of West Bengal.

5.6.2.2 Total copper

The total copper content was ranging from 16.25 to 34.00 mg kg⁻¹ soil. The variation in total copper content among the pedons might be due to variation in copper bearing minerals in the soils.

5.6.2.3 Total iron

The total iron content of these pedons varied from 0.27 to 3.17 per cent. Variation in total iron among the pedons could be attributed to variation in ferromagnesian minerals present in these soils. Mostly irregular distribution of total iron with depth was observed.

5.6.2.4 Total manganese

Total manganese content of these pedons varied from 176.00 to 620.00 mg kg⁻¹ soil and showed more or less a decreasing trend with depth. Such wide variation among the pedons could be ascribed to the variation in the content of manganese bearing minerals, clay, organic carbon, CEC and other associated elements (Ramakrishna Prasad, 1994).

5.7 pH, EC, ORGANIC CARBON AND AVAILABLE NUTRIENTS STATUS OF SURFACE SOIL SAMPLES

5.7.1 pH (1:2.5)

The surface soil samples of the study area were slightly acidic to moderately alkaline in reaction. The pH values of 1:2.5 soil water suspension ranged between 6.39 and 8.36. The variation in pH of the surface soil samples might be related with parent material, rainfall and topography of the area. Similar results were also observed by Walia and Rao (1997).

5.7.2 Electrical conductivity

The surface soil samples of this mandal had shown very low electrical conductivity values varying from 0.01 to 0.12 dSm⁻¹ suggesting very low amount of soluble salts and non-saline nature. Sharma *et al.*(1997) reported similar electrical conductivity values indicating the non-saline character in Inceptisols of North-West India. These results coincided with the findings of Walia and Rao (1996) and Marathe *et al.* (2003) in soils of Bundelkhand region of Uttar Pradesh and in mandarin orchards of Nagpur, respectively.

5.7.3 Organic carbon

The organic carbon content of these soil samples was found to vary between 0.41 and 0.71 per cent *i.e* low to medium. The reason for the low organic carbon content in the soils might be attributed to the prevalence of tropical condition, where the degradation of organic matter occurs at a faster rate coupled with low vegetative cover, thereby leaving less organic carbon in the soils. Similar findings were also made by Sharma *et al.* (2001) in Kathiawar region of Gujarat.

5.7.4 Available nitrogen

The surface soil samples of this mandal were low in available nitrogen with an overall index value of 1.00. This could be attributed to the less amount of organic carbon in these soils. This observation is in accordance with the results of Prasuna Rani *et al.* (1992).

5.7.5 Available phosphorus

The soils were medium in available phosphorus with a nutrient index value ranging from 1.88 to 2.00 in different revenue villages of the mandal. The overall nutrient index value of this mandal was 1.96 which indicates that the soils are medium in available phosphorus. This could be attributed to the fixation of released phosphorus by clay minerals and oxides of iron and aluminum (Vijay Kumar *et al.*, 1994).

5.7.6 Available potassium

The soils (surface samples) were medium to high in available potassium with a nutrient index value ranging from 2.13 to 2.63 in different revenue villages of the mandal. The overall nutrient index value of this mandal was 2.37 which confirms that the soils

are high in available potassium. This could be attributed to more intense weathering, release of labile K from organic residues, application of K fertilizers and upward translocation of potassium from lower depth along with capillary raise of ground water. Similar type of results were reported by Sharma and Anil Kumar (2003) and Hirekurabar *et al.* (2000).

5.7.7 Available sulphur

The soils of this mandal were deficient in available sulphur and overall mean of all the revenue villages was found to be 6.21 mg kg⁻¹ soil with a range of 3.29 to 9.82 mg kg⁻¹ soil. Negligible use of organic manures and sulphur containing fertilizers have led to low available sulphur content in these soils. Similar results were also obtained by Bhatnagar *et al.* (2003) in soils of Shivpuri district of Madhya Pradesh.

5.7.8 Micronutrient

5.7.8.1 Available zinc

Available zinc content in surface soil samples was low with an overall mean for all the revenue villages of the mandal was found to be 0.58 mg kg⁻¹ soil with a range of 0.21 to 1.04 mg kg⁻¹

soil. Considering 0.6 mg kg^{-1} soil as critical level (Lindsay and Norvell, 1978) for available zinc, these soils were considered as deficient in available zinc. Less available zinc in these soils was due to low amount of organic carbon. Similar views were expressed by Satyavathi and Suryanarayan Reddy (2004) and Dipak Sarkar *et al.* (2000) in soils of Telangana region of Andhra Pradesh and in Loktak catchment area of Manipur.

5.7.8.2 Available copper

The overall mean of all the revenue villages was 0.70 mg kg^{-1} soil with a range of 0.21 to 1.32 mg kg^{-1} soil. Considering 0.2 mg kg^{-1} soil (Lindsay and Norvell, 1978) as the critical limit of DTPA extractable copper for normal plant growth, it may be inferred that all the soils contain adequate amount of available copper. Maji *et al.* (1993) reported that the availability of copper in coastal soils of Sunderbans, West Bengal was largely controlled by the soil organic matter, since it was positively correlated with organic carbon. Similar results were also reported by Satyavathi and Suryanarayan Reddy (2004) and Bhaskar *et al.* (2004) in soils of Telangana region of Andhra Pradesh and in upland soils of Meghalaya, respectively.

5.7.8.3 Available iron

The overall mean of available iron content was found to be 3.20 mg kg⁻¹ soil with a range of 1.09 to 5.82 mg kg⁻¹ soil. Considering 4.5 mg kg⁻¹ soil (Lindsay and Norvell, 1978) as the critical limit of DTPA-extractable iron for normal plant growth, it may be inferred that the soils of this mandal were deficient in available iron. The wide variation in the DTPA-extractable iron content could be due to variation in organic carbon content and differences in soil properties. Similar observations were also made by Thangasamy *et al.* (2005), Satyavathi and Suryanarayan Reddy (2004) and Samanta *et al.* (2002) in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh, soils of Telangana in Andhra Pradesh and in soils of West Bengal, respectively.

5.7.8.4 Available manganese

The available manganese content ranged from 4.39 to 12.71 mg kg⁻¹ soil with an overall mean of all the revenue villages was 8.28 mg kg⁻¹ soil. The available manganese content was sufficient because these value are well above the critical limit (1.0 mg kg⁻¹ soil) of Lindsay and Norvell (1978). These observations were in

good agreement with the findings of Bhaskar *et al.* (2004), Patil and Jagdish Prasad (2004) and Dipak Sarkar *et al.* (2000) in soil of Maghalaya, Dindori district of Madhya Pradesh and in soils of Bihar, respectively.

In conclusion, the surface soil samples of the Ramachandrapuram mandal were slightly acidic to moderately alkaline, non-saline, low in organic carbon and available nitrogen, medium in available phosphorus, high in available potassium and deficient in available sulphur. The DTPA-extractable micronutrients in the surface soil samples of Ramachandrapuram mandal were deficient in available zinc and iron whereas well supplied with available copper and manganese.

5.8 CLAY MINERALOGY

The clay fraction of soils in the present study was found to be a mixture of three clay minerals *viz.*, smectite, illite and kaolinite.

Semi-quantification of X-RDA diffractograms of clay fraction showed that smectite ranged from 26.68 to 69.40 per cent, kaolinite from 9.24 to 70.80 per cent, illite from 6.80 to 34.38 per cent and feldspars from 1.78 to 39.06 per cent, respectively in these soils. Smectite was the single most dominant mineral in pedons 1, 2 and 5 than other minerals whereas kaolinite was the dominant mineral in pedons 4 and 6. Feldspars was the dominant mineral in pedon 3 and illite was dominant in pedon 7.

Transformation and neo-formation are the principal processes in the genesis of clay minerals. Transformation modify a clay mineral without altering its structure while neo-formation leads to formation of new mineral. The process of elimination and recombination led to formation of 2:1 (or) 1:1 type minerals (Padro *et al.*, 1969).

Smectite was the single dominant mineral in pedons 1, 2 and 5 than other minerals. It is quite unlikely that such a high amount of smectite in these soils could be produced during the low rainfall period of the present semi-arid conditions (Bhattacharyya *et al.*, 1993). Smectite was also formed possibly from plagioclase during

earlier geologic period and is an ephemeral in humid environment (Tardy *et al.*, 1973; Bhattacharyya *et al.*, 1993), however its retention is possible because of climate change from humid to semi-arid during Pleistocene transition period (Pal *et al.*, 1989).

Kaolinite is the dominant clay mineral in pedons 4 and 6, which contain more than 40 per cent of kaolinite. Kaolinite present in these pedons might have been formed from smectite (Bhattacharyya *et al.*, 1993). Kaolinite minerals could be formed by neosynthesis from the products of hydrolytic decomposition of feldspars and other primary minerals (Murali *et al.*, 1978; Rengasamy *et al.*, 1978) and by conversion of smectite or vermiculite to kaolinite following hydroxy interlayering in the expandable mineral or mixed layering between 2:1 and 1:1 layers (Pal *et al.*, 1989; Bhattacharyya *et al.*, 1993, 2000). Further, the kaolinite was formed in an earlier geological period with more rainfall and greater fluctuations in temperature (Pal and Deshpande, 1987). However, the study area is also experiencing the above conditions, which may lead to the synthesis of kaolinite mineral in the pedons 4 and 6.

Illite was the dominant mineral in pedon 7 and present in small quantities in all the pedons. Illite present in the clay might have been derived by alteration of micas from the parent material. Potassium bearing minerals of rocks under the prevailing conditions of the soil formation had led to formation of illitic type of minerals (Satyanarayana and Biswas, 1970).

Feldspar was the dominant clay mineral in pedon 3 and is present in small quantities in all the pedons which might have been derived from coarser alluvial sediments by physical weathering.

5.9 TAXONOMIC CLASSIFICATION

Based on the morphological characteristics of the typifying pedons, physical, physico-chemical and chemical characteristics of the soils and climate of the area, the seven pedons selected from the Ramachandrapuram mandal of Chittoor district, Andhra Pradesh were classified upto family level according to the specifications laid down by the Soil Survey Staff (1998)

CLASSIFICATION OF PEDONS 2, 5, 6 AND 7

At order level

- a) Soils are of recent origin. According to Rao *et al.* (1991) the alluvial deposits of Andhra Pradesh were of recent origin (2 million years old)
- b) No development of pedons / horizonation
- c) Absence of any diagnostic subsurface horizon.

Singh and Agrawal (2003) reported that the absence of diagnostic subsurface horizon in the profiles was one of the most important criteria for Entisols.

Based on the above features these four pedons were classified as "Entisols" at order level.

At Sub-order level

Pedon 2 had loamy fine sand to sandy texture in the control section, not exhibited any diagnostic horizon and did not permanently saturated with water. Hence, this pedon was keyed out as "Psamments" at sub-order level. Verma *et al.* (2001) and Swarnam *et al.* (2004) classified the Entisols of Punjab and Shahibi basin of Haryana and Delhi into Psamments at sub-order level, respectively.

Pedon 6 and 7 were characterised by

- a. Did not permanently saturated with water and matrix was not reduced in all the horizons below 25 cm from the mineral soil surface.
- b. Depth of the pedon was less than 100 cm and 3 per cent or more (volume) fragments of diagnostic horizons were not observed.
- c. Absence of rock fragments and a texture of loamy fine sand or coarser.
- d. Not showed 0.2 per cent or more organic carbon of Holocene age at a depth of 125 cm below the mineral soil surface or an irregular decrease in the content of organic carbon.
- e. Showed decrease in organic carbon with depth.

Hence, these two pedons were grouped under "Orthents" at sub-order level. Similar findings were also reported by Singh and Mishra (1996) who reported that soils of Gandak command area of Bihar were also classified into Orthents at sub-order level.

Pedon 5 exhibited the following features.

- a. Slope less than 25 per cent
- b. An irregular decrease in the organic carbon from 25 cm to lithic contact.
- c. Warmer than cryic.

Based on the above features the pedon 5 was classified as "Fluvents" at sub-order level. Dhaliwal *et al.* (1996) classified the flood plain soils of Punjab into Fluvents as they showed an irregular decrease of organic carbon. Similarly Sidhu *et al.* (1999) also classified the Entisols of Jammu region into Fluvents at sub-order level.

At great group level

Pedon 2 did not have aridic, xeric and udic moisture regimes but had "ustic" moisture regime. Hence, the pedon was placed under "Ustipsamments" at great group level. Verma *et al.* (2001) classified the soils of Etawah district of Uttar Pradesh as Ustipsamments. Similar results were also reported by Sidhu *et al.* (2000).

Pedons 6 and 7 have ustic moisture regime. Hence, these pedons were classified as "Ustorthents" at great group level. Singh *et al.* (1993) reported that the soils developed from Mahananda alluvium were classified as Ustorthents at great group level.

Pedon 5 also had an ustic soil moisture regime. Hence, it is keyed out as "Ustifluvents" at great group level. Sharma *et al.* (1996) also classified the soils in a topo-sequence over basaltic terrain into Ustifluvents.

At Sub-group level

Pedon 2 was characterised by

- a. Absence of lithic contact within 0.5 m of the mineral soil surface.
- b. Was not saturated with water within 1 m of the mineral soil surface.
- c. Did not have prominent redox and aquic conditions.
- d. Not had frigid or mesic or thermic or hyperthermic or isomesic soil temperature regimes.
- e. Absence of lamellae within 2 m of the soil surface.
- f. Not exhibited munsell colour notation of 2.5 YR hue and value (moist) of 3 or less,

Hence, pedon 2 was grouped under "Typic Ustipsamments". Based on the similar features Vadivelu and Bandyopadhyay (1997) classified the sandy soils of Minicoy island of Lakshadweep as Typic Ustipsamments at sub-group level.

Pedon 6 and 7 did not show the following characteristics

- a. Lithic contact within 50 cm of the mineral soil surface.
- b. Frigid, mesic or thermic or hyper thermic cracks within 125 cm of the mineral surface that are 5 mm or more wide to a thickness of 30 cm or more to linear extensibility of 6 cm or more.
- c. Redox depletions of chroma 2 or less
- d. Durinodes
- e. Cinders, pumice like fragments
- f. 50% or more (by volume) worm holes, worm costs and filled animal burrows in any horizon.

Due to the absence of above characteristics the pedon 6 and 7 were placed under "Typic Ustorthents" at sub-group level. Nayak *et al.* (2004) classified the Saragwada soils, Gujarath into Typic Ustorthents at subgroup level.

Pedon 5 did not show intergradation with any other taxa or any extra gradation from the central concept. Hence, it is logically classified as "Typic Ustifluvents" at sub-group level. Sharma *et al.* (2001) classified the dissected alluvial plains of Haldi Ghati region of Rajasthan as Typic Ustifluvents. Similar classification was also given by Sharma *et al.* (1996).

CLASSIFICATION OF PEDONS 1 AND 3

At order level

Following features in the sub-surface horizons within a depth of 0.23 to 1.57 m in pedon 1 and 0.14 to 2.08 m in pedon 3 (with a thickness of > 15 cm) were observed.

- a. Texture was finer than very fine sand or loamy very fine sand.
- b. Absence of rock structure
- c. Did not have anthropic, histic, melanic, mollic, plaggen and umbric epipedons.
- d. Absence of duripan, fragipan, argillic, calcic, gypsic, natric, oxic, petrocalcic, petrogypsic, placic and spodic sub-surface horizons.

- e. Absence of cementation or induration.
- f. Regular decrease in the amount of organic carbon with depth.

The presence of cambic sub-surface diagnostic horizon in these two pedons is recognized by the above features. Jagdish Prasad *et al.* (2001) reported that the presence of cambic sub-surface horizon was the diagnostic criteria for Inceptisols.

Hence, these two pedons are keyed out as "Inceptisols" at order level. Kadao *et al.* (2003) classified the typical banana growing soils of Wardha district of Maharashtra into Inceptisols based on the presence of cambic horizon.

At sub-order level

These soils (Pedon 1 and 3) had ustic soil moisture regime. Hence, these pedons were classified as "Ustepts" at this category. Sharma *et al.* (2004) classified the soils of southern Rajasthan as Ustepts due to the presence of ustic soil moisture regime at great group level.

At great group level

Pedons 1 and 3 are not having either duripan or calcic horizon and the base saturation is more than 60 per cent at a depth between 0.25 to 0.75 m from the soil surface. These characters indicated that these pedons represented the central concept of usteps. So, the pedons 1 and 3 were grouped under "Haplustepts" at great group level. Patil and Jagdish Prasad (2004) placed the *sal* supporting soils in Dindori district of Madhya Pradesh as Haplustepts at great group level.

At Sub-group level

Pedons 1 had vertic features like cracks of 3 to 5 mm wide to a depth of 35 cm and slickensides in the lower horizons. Due to the presence of these vertic characters, this pedon was classified as "Vertic Haplustepts". Ramprakash and Seshagiri Rao (2002) classified the Inceptisols of Krishna district of Andhra Pradesh as Vertic Haplustepts due to the presence of cracks and slickensides. Similar findings were also reported by Satyavathi and Suryanarayan Reddy (2004) who classified the soils of Madhira, Khammam and Sangareddi in Andhra Pradesh as Vertic Haplustepts due to the presence of cracks and slickensides.

Pedon 3 had the following characters.

- a. Did not have lithic contact within 50 cm from the soil surface
- b. Absence of andic properties and aquic conditions within 75 cm depth from the surface.
- c. Did not have umbric or mollic epipedons.
- d. Not showed the vertic properties.
- e. Absence of lamellae, calcic and gypsic sub-surface horizons.
- f. Did not have aridic temperature regime and udic moisture regime.
- g. Had more than 60 per cent base saturation in all the horizons of the profile.

The above pedon did not exhibit intergradation with other taxa or an extragradation from the central concept. Hence, pedon 3 is logically classified as "Typic Haplustepts" at sub-group level. Ramesh *et al.* (2002) classified the Inceptisols of Singarayakonda mandal in the Prakasam district of Andhra Pradesh as Typic Haplustepts at sub-group level.

CLASSIFICATION OF PEDON 4

The pedon 4 is placed under the order "Alfisols" due to the following characteristics

- a. Presence of diagnostic argillic sub-surface horizon.
- b. Absence of plaggen epipedon.
- c. Did not have spodic or oxic sub-surface horizons above the argillic horizon.

Further, the argillic horizon was developed due to clay illuviation and was identified by the presence of the following characteristics.

- a. Clay content was greater than 1.2 times in the fine earth fraction of illuvial horizon than that of eluvial horizon, since the clay content in the eluvial horizon is above 15 per cent.
- b. The thickness of the horizon is more than 7.5 cm and also more than one-tenth as thick as the sum of the thickness of all the overlying horizons.
- c. Presence of clay cutans (Argillans)
- d. The base saturation was more than 35 per cent through out the depth of the horizon.

Based on the similar conditions, Dipak Sarkar *et al.* (2001) classified the Teltaka series soils of Chhotanagpur plateau into Alfisols.

At Sub-order level

Pedon 4 had ustic soil moisture regime. Hence, this pedon was grouped under "Ustalfs" at this category. Walia and Rao (1996) classified the soils of Bundelkhand region of Uttar Pradesh as Ustalfs at sub-order level based on the ustic soil moisture regime.

At greatgroup level

Pedon 4 had shown the following characteristics

- a. Not had either duripan, plinthite, kandic or petro-calcic horizon.
- b. The argillic horizons not exhibited a hue of 2.5 YR and moist value of 3.

Hence this pedon is grouped as "Haplustalf" at great group level. Jagannadham *et al.* (1995) classified the red soils of Kandukur division of Andhra Pradesh as Haplustalfs. Similar results were also reported by Singh and Mishra (1996).

At sub-group level

Pedon 4 exhibited the following features

- a. Absence of lithic contact or paralithic contact within 100 cm from the soil surface.
- b. Did not have cracks, wedge shaped aggregates and redox conditions.
- c. Argillic horizon with more than 75% base saturation.
- d. Absence of pumice or pumice like fragments and volcanic ash
- e. Absence of lamellae, sandy particle size class and clastic horizons.
- f. Presence of iso-hyperthermic soil temperature regime and also moisture control section is dry for more than 120 cumulative days per year.

Hence, the pedon 4 was classified as “Typic Haplustalfs” at sub-group level. Dutta *et al.* (2001) classified the soils of Hindupur taluk in Anantapur district of Andhra Pradesh as Typic Haplustalfs at sub-group level. Similar findings were also reported by Ramesh *et al.* (2002).

Classification of pedons at family level

Particle size classes

All the seven pedons contained more than 18 per cent and less than 35 per cent clay in the control section which led the soils to be grouped under '**Fine-loamy**' particle size class. (Soil Survey Staff, 1999).

Mineralogy classes

Pedons 2, 5, 6, and 7 had contained more than 80 per cent silica in the control section. Hence, the mineralogy class for these pedons is "siliceous". The mineralogy class for the pedon 4 is "kaolinitic" since the clay mineral kaolinite contributed to more than 40 per cent in the clay fraction of the pedon. Pedon 1 showed the dominance of "smectitic" clay mineral in the clay fraction. Hence, the mineralogy for the this pedon is "smectitic". However pedon 3 is placed under "mixed" mineralogy class as no mineral was present to an extent of 40 per cent in the clay fraction. (Soil Survey Staff, 1999)

Soil temperature classes

MAST was computed from the MAAT by adding 3.5°C. The Ramachandrapuram mandal was classified under megathermic temperature regime because of the prevailing mean annual soil temperature (31.91°C). MAST of 28°C was used as the limit to separate hyperthermic from megatherimic (Sehgal, 1996).

MSST of the study area was 32.07 °C which was computed by adding 2.5°C to the MSAT and deducting the amplitudinal correction factor (0.82°C). The MWST of the study area was 27.75 °C calculated by adding 2.5°C to the MWAT (24.43 °C) and adding amplitudinal correction factor (0.82°C). According to Sehgal (1996) the study area was placed under megathermic temperature regime.

Soil Survey Staff (1998) recognized June, July and August as summer months and December, January and February as winter months for the places in northern hemisphere. As per these criteria the difference between mean summer and winter temperatures was less than 6°C and mean annual temperature was more than 22°C. Therefore, the temperature regime of the study area was classified as “iso-hyperthermic”.

Classification of pedons upto family level

Based on morphological, physical, physico-chemical, chemical, mineralogical and meteorological data, the soils of Ramachandrapuram madal were classified as:

- Pedon 1 : Fine-loamy, smectitic,
iso - hyperthermic, Vertic Haplustepts
- Pedon 2 : Fine-loamy, siliceous,
iso-hyperthermic, Typic Ustipsamments.
- Pedon 3 : Fine-loamy, mixed,
iso-hyperthermic, Typic Haplustepts
- Pedon 4 : Fine-loamy, kaolinitic,
iso-hyperthermic, Typic Haplustalfs.
- Pedon 5 : Fine-loamy, siliceous,
iso-hyperthermic, Typic Ustifluvents.
- Pedon 6 : Fine-loamy, siliceous,
iso-hyperthermic, Typic Ustorthents.
- Pedon 7 : Fine-loamy, siliceous,
iso-hyperthermic, Typic Ustorthents.

5.10 LAND CAPABILITY CLASSIFICATION

The land capability classification is the grouping of a land unit (s) into defined class (es) based on their capability. It is a broad grouping of soils based on their limitations and is designed

to emphasis the hazards in different kinds of soils. It serves as a guide to assess suitability of the land for arable crops, grazing and forestry. The use of land without paying due regard to its capability results in progressive decline in crop yields.

It requires extra inputs and efforts to sustain crop productivity from such a declining soil resource. Thus the land capability classification is assigned primarily for soil conservation and is intended for determining the maximum intensity of land use consistent with low erosion risks and sustained productivity.

Based on soil properties, the soils of Ramachandrapuram mandal have been classified into three land capability classes *viz.*, class II, III and IV and a suitable land use plan has been suggested (Table 29). Pedons 1 and 3 were having slight limitations of soil. Hence, tentatively placed under land capability sub-class IIs. Further, similar land capability classification was suggested to the soils developed from basaltic terrain (Sharma *et al.*, 1996). Singh and Mishra (1996) had also given the tentative classification of IIs for Entisols (Typic Ustorthents) and Inceptisols (Typic Eutrochrepts) of Gandak command area of Bihar. The

suggested land use plan for the pedons 1 and 3 is double cropping including legumes in rotation with the addition of manures and fertilizers and need moderate soil and water management practices. Groundnut, redgram and sugarcane crops can also be grown in these soils.

Pedon 2 was placed under capability sub-class IIIs. Pedon 2 is having sandy texture in the sub-surface with high permeability and low water holding capacity. The management practices suggested for pedon 2 includes addition of tank silt (pond mud) to improve the sub-soil texture. Vegetables, pulses and oil seeds can be preferred.

Pedons 4 and 5 were classified into capability sub-class IIIs due to very gentle slope, slight erosion, moderate runoff and moderate water holding capacity. Similarly Dipak Sarkar *et al.* (2002) placed the soils of loktak command area of Manipur under land capability sub-class IIIs. These soils require proper conservation measures like contour bunding and contour farming to protect the soils against erosion. Horticultural crops like mango, sapota, guava, vegetables and agricultural crops like sugarcane,

pulses and oil seeds can also be grown with proper soil management practices (Patel *et al.*, 2001). Similarly, Thangasamy (2005) also classified soils of Typic Ustifluvents and Typic Rhodustalfs into land capability sub-class IIIes in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh.

Pedons 6 and 7 were classified into land capability sub-class IVes due to strong limitations such as shallow depth, gentle slope, moderate erosion and poor nutrient status. Addition of tank silt (pond mud) is recommended and very careful soil and water management practices could be followed and fruit crops like pomegranate can be grown.

Table 29: Interpretation of soils of Ramachandrapuram mandal

Pedon No.	Tentative soil series	Land capability class with limitations	Description	Major limitations	Suggested land use
1.	Ramachandrapuram	IIs	Good cultivable land for sustainable agriculture	Impeded sub-surface drainage, poor soil aeration, severe soil tillage problems and high shrink swell potential	Climatically adopted double cropping including legume in rotation with the addition of optimum dose of fertilizers and manures. Sugarcane can also be grown
2.	Nennuru	IIIs	Moderately good cultivable land for sustainable agriculture	Sandy texture in the subsurface, high permeability, low water holding capacity and poor nutrient holding capacity.	Suitable for horticultural crops like mango, sapota, guava and pomegranate.
3.	Sorakayalapalem	IIs	Good cultivable land for sustainable agriculture	High permeability, poor nutrient status	Climatically adopted double cropping including legume in rotation with the addition of optimum dose of fertilizers and manures. Sugarcane can also be grown
4.	Gangireddipalli	IIIs	Moderately good cultivable land for sustainable agriculture	Slight erosion, very gentle slope, low nutrient status	Horticultural crops like mango, sapota, guava, custard apple can be grown. Vegetables, sugarcane, pulses and oil seeds can be grown.

Table 29..Contd...

Pedon No.	Tentative soil series	Land capability class with limitations	Description	Major limitations	Suggested land use
5.	Sanjeevarayapuram	IIIes	Moderately good cultivable land for sustainable agriculture	Very gentle slope, high permeability, slight erosion and low nutrient status.	Horticultural crops like mango, sapota, guava, custard apple can be grown. Vegetables, sugarcane, pulses and oil seeds can be grown.
6.	C.K. Palli	IVes	Fairly good cultivable land for sustainable agriculture	Gentle slope, moderate erosion, shallow depth, moderate runoff, high permeability and poor nutrient status.	Addition of tank silt (pond mud) is recommended and very careful soil and water management practices could be followed. Fruit crops like pomegranate can be grown.
7.	Nethakuppam	IVes	Fairly good cultivable land for sustainable agriculture	Gentle slope, moderate erosion, shallow depth, moderate runoff, high permeability and poor nutrient status.	Addition of tank silt (pond mud) is recommended and very careful soil and water management practices could be followed. Fruit crops like pomegranate can be grown.

CHAPTER – IV

SUMMARY AND CONCLUSIONS

The present investigation was undertaken to study the morphology and taxonomy of soils in Ramachandrapuram mandal of Chittoor district in Andhra Pradesh.

Seven representative pedons were selected in seven different locations of Ramachandrapuram mandal covering all types of soils. All these seven pedons were studied in detail and described for their morphological characteristics. The horizon-wise samples collected from these pedons were processed and analysed for physical properties *viz.*, particle size analysis, soil density, water holding capacity, volume expansion, pore space and LOI; physico-chemical properties like pH, EC, organic carbon and CaCO_3 ; electro-chemical characteristics such as CEC, exchangeable bases and base saturation; chemical composition (SiO_2 , Al_2O_3 , Fe_2O_3 , CaO , MgO , P_2O_5 , Na_2O and K_2O) and total nutrients (N, P, K, S, Zn, Cu, Fe and Mn) status.

Eighty surface soil samples were also collected from different revenue villages of the mandal and processed for laboratory analysis of pH, EC, organic carbon, available macronutrients (N, P, K and S) and micronutrients (Cu, Zn, Fe and Mn) to know the fertility status of the mandal. Clay mineral analysis was carried out to identify relative proportion of various clay minerals in the soil samples collected from the control section of each pedon. An attempt was also made to classify the soils of the mandal into different land capability classes for suggesting an optimum land use plan.

The study area was under the influence of semi-arid monsoonic climate with a mean annual rainfall and air temperature of 1205.96 mm and 28.04°C, respectively. However, distinct summer, rainy and winter seasons were existing in the Ramachandrapuram mandal.

The pedon 2 was developed from alluvium whereas the remaining pedons were originated from granite-gneiss parent material. These pedons were occurring on plain to gently sloping topography.

All the pedons were moderately deep to very deep in depth. These pedons were characterised by AC (pedons 2, 5, 6 and 7), AB (pedons 1 and 3) and AEB (pedon 4) profiles. The colour was varying from yellowish brown to very dark grayish brown in pedons 1, 2, 3 and 7, dark red to dark brown in pedon 4, yellowish red to light yellowish brown in pedon 5 and dark red to yellowish brown in pedon 6.

The morphological features indicated that these pedons in general had fine to coarse texture and crumb, sub-angular blocky, angular blocky and single grain structure. Pedons 2, 5, 6 and 7 did not exhibit any diagnostic horizon. Further, pedons 1 and 3 showed cambic (Bw) sub-surface diagnostic horizon whereas pedon 4 exhibited argillic (Bt) sub-surface diagnostic horizon. Vertic properties like cracks and slickensides and strong effervescence were identified in pedon 1 only.

The clay content increased with depth in pedon 1 whereas pedon 5 and 7 showed a decreasing trend. Pedon 2 exhibited an irregular decreasing trend and pedons 3, 4 and 6 have shown no specific trend with depth. Physical constants like water holding

capacity, loss on ignition and volume expansion followed the trend of clay content. Pore space exhibited a decreasing trend with depth in case of pedons 2, 5 and 7 and increasing trend in pedons 1 and 3. However, the remaining pedons showed an irregular trend with depth. All these pedons recorded an increasing trend of bulk density with depth corresponding to decreasing organic carbon content with depth.

All the pedons were slightly acidic to moderately alkaline in reaction, non-saline and low to medium in organic carbon content. All these pedons registered lesser per cent of CaCO_3 .

CEC values of these pedons were low to medium. More or less increasing trend with depth was observed in pedons 1, 3 and 4 whereas the remaining pedons showed more or less decreasing trend with depth. The exchange complex was dominated by Ca^{2+} followed by Mg^{2+} , Na^+ and K^+ .

The silica content was more or less decreased with depth in pedons 1, 3 and 4 while the remaining pedons showed an irregular increasing trend with depth. Further, $\text{SiO}_2/\text{R}_2\text{O}_3$, $\text{SiO}_2/\text{Al}_2\text{O}_3$,

$\text{SiO}_2/\text{Fe}_2\text{O}_3$ and $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ ratios were higher in all the soils indicating the siliceous nature of the parent material. $\text{SiO}_2/\text{R}_2\text{O}_3$ and $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratios decreased with depth in pedons 1, 3 and 4 while increasing trend was noticed in the remaining pedons. Pedons 1, 3 and 4 showed a decreasing trend of $\text{SiO}_2/\text{Fe}_2\text{O}_3$ with depth while the remaining pedons exhibited more or less increasing trend with depth. Further, a decreasing trend of $\text{Al}_2\text{O}_3/\text{Fe}_2\text{O}_3$ with depth in pedons 1, 2 and 3 was observed while the remaining pedons showed an irregular increase with depth.

Regarding the fertility status, the surface soil samples were low in available nitrogen, low to medium in available phosphorus, medium to high in available potassium and deficient in available sulphur. As far as cationic micronutrients status is concerned, the available zinc and iron were deficient while the available copper and manganese were sufficient.

X-ray diffraction analysis of clay samples revealed that the pedons 1, 2 and 5 showed the dominance of smectite clay mineralogy whereas pedons 4 and 6 exhibited dominance of

kaolinite clay mineralogy. However, pedons 3 and 7 showed the dominance of feldspars and illite, respectively.

Based on morphological, physical, physico-chemical, chemical, mineralogical and meteorological data, the soils of Ramachandrapuram mandal were classified as:

Pedon 1: Fine-loamy, smectitic, iso-hyperthermic,
Vertic Haplustepts

Pedon 2: Fine-loamy, siliceous, iso-hyperthermic,
Typic Ustipsamments

Pedon 3: Fine-loamy, mixed, iso-hyperthermic,
Typic Haplustepts

Pedon 4: Fine-loamy, kaolinitic, iso-hyperthermic,
Typic Haplustalfs

Pedon 5: Fine-loamy, siliceous, iso-hyperthermic,
Typic Ustifluvents

Pedon 6: Fine-loamy, siliceous, iso-hyperthermic,
Typic Ustorthents

Pedon 7: Fine-loamy, siliceous, iso-hyperthermic,
Typic Ustorthents

Tentative interpretative grouping of soils into land capability sub-classes was as follows:

Pedons 1 and 3 fall under land capability sub-class IIs. These are good cultivable lands with slight limitations [impeded sub-surface drainage (pedon 1) and high permeability (pedon 3)]. Pedon 2 was classified under land capability sub-class IIIs. These are moderately good cultivable lands with moderate limitations of soil (sandy texture in sub-surface and poor nutrient holding capacity).

Pedons 4 and 5 were placed under land capability sub-class IIIs. These are moderately good cultivable lands with moderate limitations of erosion and soil (slight erosion and very gentle slope). Pedons 6 and 7 were grouped under land capability sub-class IVes which are fairly good cultivable lands with severe limitation of erosion and soil *i.e.*, gentle slope, moderate erosion and shallow depth.

In conclusion, the analysis of soils of Ramachandrapuram mandal revealed that the soils were deficient in organic carbon, available N, P, Zn and Fe. Hence, judicious use of organic manures in combination with inorganic fertilizers not only helps to achieve sustainable yields of crops but also maintains the soil health without deterioration.

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APPENDIX - A

PEDON 1

I. Soil site description

a. Village	:	Ramachandrapuram
b. Physiography	:	Plain lands
c. Slope	:	Degree : 0-1% (Nearly level)
		Class : A
		Aspect : NW-NE
d. Parent material	:	Granite - gneiss
e. Natural vegetation	:	<i>Parthenium hysterophorus</i> and grasses
f. Land use	:	Sugarcane, redgram, paddy and groundnut
g. Erosion	:	Nil
h. Drainage	:	Imperfectly drained
i. Ground water depth	:	Below 20 m
j. Location	:	On the side of the main road that proceeds to Nennur and 1 km away from Ramachandra- puram mandal office.

II. Brief description of the typifying pedon

Horizon	Depth (m)	Morphometric characters
Ap	0.00 - 0.23	Very dark grayish brown (10 YR 3/2) dry and moist; sandy clay loam; medium, moderate, sub-angular blocky; slightly hard, firm, slightly sticky slightly plastic; few fine pores; few medium roots; diffuse wavy boundary.
Bw1	0.23 - 0.61	Very dark brown (10 YR 2/2) dry and moist; sandy clay loam; medium, weak, sub-angular blocky; hard, firm, slightly sticky slightly plastic; few fine pores; diffuse wavy boundary.
Bw2	0.61 - 1.08	Very dark grayish brown (10 YR 3/2) dry, very dark gray (10 YR 3/1) moist; clay loam; fine, weak, angular blocky; hard, very firm, slightly plastic; few, fine pores; diffuse wavy boundary.
Bw3	1.08 - 1.57+	Dark yellowish brown (10 YR 4/4) dry dark yellowish brown (10 YR 4/6) moist; clay loam; medium, moderate, sub-angular blocky; slightly hard, very firm, slightly sticky slightly plastic; strong effervescence; few fine pores; clear smooth boundary.
Other features		i. Cracks of 3 to 5 mm wide to a depth of 35 cm. ii. Indistinct and weak slickensides below the surface horizon.
Taxonomic unit	:	Fine-loamy, smectitic, iso-hyperthermic, Vertic Haplustepts
LCC (tentative interpretative grouping)	:	IIs

PEDON 2

I. Soil site description

a. Village	:	Nennuru
b. Physiography	:	Plain lands
c. Slope	:	Degree : 0-1% (Nearly level)
		Class : A
		Aspect : NW-SE
d. Parent material	:	Alluvium
e. Natural vegetation	:	<i>Lantana camara</i> and grasses
f. Land use	:	Groundnut, sorghum and coconut
g. Erosion	:	Nil
h. Drainage	:	Imperfectly drained
i. Ground water depth	:	Below 20 m
j. Location	:	On the left side of the Rama-chandrapuram – Nennuru road and 1.5 km from Nennuru

II. Brief description of the typifying pedon

Horizon	Depth (m)	Morphometric characters
Ap	0.00 - 0.20	Very dark grayish brown (10 YR 3/2) dry, very dark gray (10 YR 3/1) moist; sandy clay loam; medium, moderate, sub-angular blocky; slightly hard, friable, slightly sticky slightly plastic; few fine pores; few fine roots; clear smooth boundary.
A1	0.20 - 0.67	Brown (7.5 YR 4/4 dry and moist); sandy clay loam; medium, moderate, sub-angular blocky; slightly hard, friable, slightly sticky slightly plastic; few fine pores; diffuse wavy boundary.
A2	0.67 - 0.92	Brown (7.5 YR 4/4 dry and moist); sandy loam; medium, moderate, sub-angular blocky; slightly hard, friable, slightly sticky slightly plastic; few fine pores; diffuse wavy boundary.
C1	0.92 - 1.24	Strong brown (7.5 YR 4/6 dry and moist); loamy sand; coarse, weak, crumb; loose, very friable, non-sticky non-plastic; few fine pores; diffuse wavy boundary.
C2	1.24 - 1.55	Light brown (7.5 YR 6/4) dry, strong brown (7.5 YR 5/6) moist; sandy; coarse, structureless, single grain; loose, loose, non-sticky non-plastic; common coarse pores; clear smooth boundary.
C3	1.55 - 1.83+	Light brown (7.5 YR 6/4) dry, strong brown (7.5 YR 5/6) moist; sandy; coarse, structureless, single grain; loose, loose, non-sticky non-plastic; common coarse pores; diffuse wavy boundary.
Other features		Fine-loamy, siliceous, iso-hyperthermic, Typic Ustipsamments
LCC (tentative interpretative grouping) :		III _s

PEDON 3

I. Soil site description

a. Village	:	Sorakayalapalem
b. Physiography	:	Plain lands
c. Slope	:	Degree : 0-1% (Nearly level)
		Class : A
		Aspect : NW-NE
d. Parent material	:	Granite - gneiss
e. Natural vegetation	:	<i>Parthenium hysterophorus</i> <i>Acalypha indica</i> and <i>Lucas aspera</i>
f. Land use	:	Mango, groundnut and sugarcane
g. Erosion	:	Nil
h. Drainage	:	Well drained
i. Ground water depth	:	Below 20 m
j. Location	:	In mango orchard which is ½ km away from Z.P. High School in Sorakayalapalem village.

II. Brief description of the typifying pedon

Horizon	Depth (m)	Morphometric characters
Ap	0.00 - 0.14	Strong brown (7.5 YR 5/6 dry and moist); silty loam; fine, weak, crumb; loose, very friable, non-sticky non-plastic; common medium pores; fine common roots; clear smooth boundary.
Bw1	0.14 - 0.44	Strong brown (7.5 YR 5/6) dry, (7.5 YR 5/4) moist; silty clay loam; medium, moderate, sub-angular blocky; slightly hard, firm, slightly sticky slightly plastic; common few pores; diffuse wavy boundary.
Bw2	0.44 - 0.79	Strong brown (7.5 YR 5/6) dry, strong brown (7.5 YR 4/6) moist; clay loam; medium moderate, sub-angular blocky; hard, firm, slightly plastic; common few pores; diffuse wavy boundary.
Bw3	0.79 - 1.16	Brown (7.5 YR 5/4) dry, brown (7.5 YR 4/4) moist; silty clay loam; medium, moderate, sub-angular blocky; soft, friable, slightly sticky slightly plastic; common few pores; diffuse wavy boundary.
Bw4	1.16 - 1.53	Brown (7.5 YR 5/4) dry, brown (7.5 YR 4/4) moist; silty clay loam; medium, moderate, sub-angular blocky; soft, friable, slightly sticky slightly plastic; common few pores; clear smooth boundary.
Bw5	1.53 - 2.08+	Light brown (7.5 YR 6/4) dry, dark brown (7.5 YR 3/4) moist; clay loam; medium, strong, sub-angular blocky; hard, firm, slightly plastic; common few pores; diffuse wavy boundary.
Taxonomic unit	:	Fine-loamy, mixed, iso-hyperthermic, Typic Haplustepts
LCC (tentative interpretative grouping)	:	IIs

PEDON 4

I. Soil site description

a. Village	:	Gangireddipalli
b. Physiography	:	Uplands
c. Slope	:	Degree : 1-3% (Very gentle sloping) Class : B Aspect : NW-SE
d. Parent material	:	Granite - gneiss
e. Natural vegetation	:	<i>Parthenium hysterophorus</i> and grasses
f. Land use	:	Paddy, groundnut and mango
g. Erosion	:	Slight erosion
h. Drainage	:	Well drained
i. Ground water depth	:	Below 20 m
j. Location	:	5 km away from Ramachandrapuram and on the right side of the road proceeding to Rayalacheruvu.

II. Brief description of the typifying pedon

Horizon	Depth (m)	Morphometric characters
Ap	0.00 - 0.17	Dark brown (10 YR 4/3 dry and moist); sandy clay loam; fine, weak, sub-angular blocky; slightly hard, firm, slightly sticky slightly plastic; few fine pores; few fine roots; clear smooth boundary.
E	0.17 - 0.36	Strong brown (7.5 YR 5/6 dry and moist); sandy loam; fine, weak, sub-angular blocky; hard, friable, non-sticky non-plastic; clear smooth boundary.
Bt1	0.36 - 0.68	Brown (7.5 YR 5/4) dry, dark brown (7.5 YR 3/4) moist; sandy clay loam; medium, moderate, sub-angular blocky; hard, firm, slightly sticky slightly plastic; clear smooth boundary.
Bt2	0.68 - 1.21	Dark grayish brown (2.5 YR 4/2 dry and moist); clay loam; coarse, moderate, sub-angular blocky; hard, firm, slightly sticky slightly plastic; diffuse wavy boundary.
Bt3	1.21 - 1.65+	Dark red (2.5 YR 3/6 dry and moist); clay loam; coarse, strong, sub-angular blocky, hard, firm, slightly sticky slightly plastic; diffuse wavy boundary.
Taxonomic unit	:	Fine-loamy, kaolinitic, iso-hyperthermic, Typic Haplustalfs
LCC (tentative interpretative grouping)	:	Illes

PEDON 5

I. Soil site description

a. Village	:	Sanjeevarayapuram
b. Physiography	:	Uplands
c. Slope	:	Degree : 1-3% (Very gentle sloping) Class : B Aspect : NW-SE
d. Parent material	:	Granite - gneiss
e. Natural vegetation	:	<i>Calotropis gigantea</i> , <i>Azadiracta indica</i> and <i>Parthenium hysterophorus</i>
f. Land use	:	Sugarcane, groundnut, mango, paddy and coconut
g. Erosion	:	Slight erosion
h. Drainage	:	Imperfectly drained
i. Ground water depth	:	Below 20 m
j. Location	:	In fallow land, 1 km away from Rayalacheruvu

II. Brief description of the typifying pedon

Horizon	Depth (m)	Morphometric characters
Ap	0.00 - 0.15	Dark brown (10 YR 3/3 dry and moist); clay loam; medium, moderate, angular blocky; hard, firm, slightly sticky slightly plastic; few fine roots; clear smooth boundary.
A1	0.15 - 0.34	Light yellowish brown (10 YR 6/4) dry, dark yellowish brown (10 YR 4/4) moist; loamy; medium, moderate, sub-angular blocky; hard, friable, slightly sticky slightly plastic; clear smooth boundary.
A2	0.34 - 0.74	Brown (7.5 YR 4/4 dry and moist); sandy clay loam; medium, moderate, angular blocky; hard, firm, slightly sticky slightly plastic; clear smooth boundary.
A3	0.74 - 0.99	Brown (7.5 YR 4/4) dry, strong brown (7.5 YR 4/6) moist; sandy loam; fine, weak, sub-angular blocky; loose, friable, non-sticky non-plastic; clear smooth boundary.
A4	0.99 - 1.14	Dark brown (7.5 YR 3/4) dry, brown (7.5 YR 4/4) moist; sandy loam; fine, weak, sub-angular blocky, loose, friable, non-sticky non-plastic; clear smooth boundary.
A5	1.14 - 1.46	Yellow red (5 YR 5/6) dry, yellowish red (5 YR 4/6) moist; sandy loam; medium, moderate, sub-angular blocky; slightly hard, friable, non-sticky non-plastic; clear smooth boundary.
A6	1.46 - 1.61+	Yellowish red (5 YR 4/6 dry and moist); sandy loam; medium, moderate, sub-angular blocky; slightly hard, friable, non-sticky non-plastic; clear smooth boundary.
Taxonomic unit	:	Fine-loamy, siliceous, iso-hyperthermic, Typic Haplustepts
LCC (tentative interpretative grouping)	:	Illes

PEDON 6

I. Soil site description

a. Village	:	C.K.Palli
b. Physiography	:	Hill slopes
c. Slope	:	Degree : 3-8% (Gentle sloping)
		Class : C
		Aspect : NW-SE
d. Parent material	:	Granite - gneiss
e. Natural vegetation	:	<i>Parthenium hysterophorus</i> and grasses
f. Land use	:	Paddy, mango and coconut
g. Erosion	:	Moderate erosion
h. Drainage	:	Moderately well drained
i. Ground water depth	:	Below 20 m
j. Location	:	In the mango orchard, 2 km away from C.K.Palli.

II. Brief description of the typifying pedon

Horizon	Depth (m)	Morphometric characters
Ap	0.00 - 0.10	Yellowish brown (10 YR 5/4) dry, dark yellowish brown (10 YR 4/4) moist; sandy clay loam; fine, weak, sub-angular blocky; hard, friable, slightly sticky slightly plastic; few fine pores; few fine roots; clear smooth boundary.
A1	0.10 - 0.26	Brown (7.5 YR 5/4) dry, brown (7.5 YR 4/4) moist; sandy clay loam; medium, moderate, sub-angular blocky; very hard, firm, slightly sticky slightly plastic; clear smooth boundary.
A2	0.26 - 0.60	Dark red (2.5 YR 3/6 dry and moist); sandy clay loam; medium, moderate, sub-angular blocky; very hard, firm, slightly sticky slightly plastic; clear smooth boundary.
Taxonomic unit	:	Fine-loamy, siliceous, iso-hyperthermic, Typic Ustorthents
LCC (tentative interpretative grouping)	:	IVes

PEDON 7

I. Soil site description

a. Village	:	Nethakuppam
b. Physiography	:	Hill slopes
c. Slope	:	Degree : 3-8% (Gentle sloping)
		Class : C
		Aspect : NW-NE
d. Parent material	:	Granite - gneiss
e. Natural vegetation	:	<i>Lantana camara</i> , <i>Tectona grandis</i> and grasses
f. Land use	:	Groundnut, sugarcane, mango and coconut
g. Erosion	:	Moderate erosion
h. Drainage	:	Moderately well drained
i. Ground water depth	:	Below 20 m
j. Location	:	In the fallow land, 2 km away from Nethakuppam

II. Brief description of the typifying pedon

Horizon	Depth (m)	Morphometric characters
Ap	0.00 - 0.10	Very dark grayish brown (10 YR 3/2 dry and moist); sandy clay loam; medium, moderate sub-angular blocky; slightly hard, friable, slightly sticky slightly plastic; few fine pores; few fine roots; clear smooth boundary.
A1	0.10 - 0.38	Yellowish brown (10 YR 5/4) dry, dark yellowish brown (10 YR 4/4) moist; sandy clay loam, medium, moderate, sub-angular blocky; hard, firm, slightly sticky slightly plastic; clear smooth boundary.
A2	0.38 - 0.62	Strong brown (7.5 YR 4/6 dry and moist); sandy clay loam; fine, moderate, sub-angular blocky; hard, firm, slightly plastic; clear smooth boundary.
A3	0.62 - 0.91	Brown (7.5 YR 4/4 dry and moist); sandy clay loam; fine, moderate, sub-angular blocky; hard, firm, slightly sticky slightly plastic; clear smooth boundary.
Taxonomic unit	:	Fine-loamy, mixed, iso-hyperthermic, Typic Ustorthents
LCC (tentative interpretative grouping)	:	IVes

APPENDIX – B (Analytical Data)

Table 1: Details of pH, EC, OC and available nutrients status of surface soil samples of different revenue villages of Ramachandrapuram mandal

S. No.	Revenue Villages and name of the Farmer	pH (1:2.5)	EC (dSm ⁻¹)	Organic carbon (%)	N ————— (kg ha ⁻¹)	P ————— (kg ha ⁻¹)	K —————	S —————	Zn —————	Cu (mg kg ⁻¹)	Fe —————	Mn —————
I.	Ramachandrapuram											
1.	P.Sivaram Reddy	8.21	0.08	0.53	118.86	16.38	235.00	5.66	0.86	0.64	3.96	11.63
2.	S.Sivasankar Reddy	8.09	0.08	0.59	136.39	21.64	270.00	4.90	0.23	0.73	4.29	10.40
3.	T.Rami Reddy	8.29	0.10	0.54	167.64	23.21	285.00	6.55	0.50	1.21	3.82	6.71
4.	P.Viswanath Reddy	7.36	0.09	0.62	93.45	15.28	305.00	3.42	0.49	0.92	2.49	8.29
5.	R.Ramesh Reddy	8.32	0.11	0.58	121.23	15.76	295.00	4.56	0.29	0.74	4.63	9.28
6.	N.Sudhakar	8.17	0.10	0.64	154.03	18.34	225.00	4.81	0.57	0.98	5.82	9.71
7.	P.Subbaiah	8.05	0.08	0.51	100.29	23.96	290.00	5.39	0.76	0.82	3.13	6.22
8.	T.Ramaraju	8.36	0.11	0.55	133.74	21.29	310.00	5.73	0.64	1.09	4.21	8.13
	Mean	8.11	0.09	0.57	125.32	19.48	276.88	5.12	0.54	0.89	4.04	8.80
II.	Nennuru											
9.	L.Niranjan	7.34	0.04	0.51	63.25	10.92	155.00	5.21	0.23	0.82	2.29	8.03
10.	P.Ramasubbaiah	7.61	0.03	0.42	79.83	11.26	290.00	6.03	0.39	0.49	2.11	5.28
11.	G.Ramanjaneyulu	7.53	0.03	0.48	86.21	10.98	145.00	6.34	0.64	0.56	4.62	4.91
12.	V.Nagasubbaih	8.04	0.04	0.62	176.91	20.32	275.00	9.31	0.32	0.72	3.71	8.36
13.	V.Vemareddy	8.02	0.01	0.46	101.73	18.36	225.00	9.82	0.71	0.59	2.86	8.18
14.	N.Nagireddy	7.92	0.05	0.52	88.28	17.39	175.00	8.62	0.54	0.87	5.38	5.28
15.	L.Lakshmaiah	7.54	0.02	0.59	74.61	21.28	160.00	4.28	0.52	0.82	1.34	9.34
16.	R.Anjan Reddy	7.86	0.01	0.48	98.64	23.29	190.00	4.91	0.49	0.64	2.93	7.61
	Mean	7.73	0.02	0.51	96.09	16.72	201.88	6.81	0.48	0.69	3.16	7.12
III.	C.K.Palli											
17.	J.Prakash Naidu	7.32	0.04	0.53	98.82	21.28	290.00	5.53	0.59	0.74	2.32	7.64
18.	T.Babu	7.28	0.05	0.51	86.08	19.03	135.00	4.72	0.68	0.43	1.09	8.31
19.	C.Dilhi Prasad	6.39	0.04	0.52	72.62	16.72	225.00	3.69	0.34	0.72	2.61	7.63
20.	D.Reddiramu	6.86	0.04	0.46	87.32	16.55	295.00	4.28	0.72	0.69	3.21	7.14
21.	G.Balkrishnam Naidu	7.13	0.01	0.49	63.11	18.39	175.00	6.29	0.79	0.54	3.03	4.28
22.	S.Srinivasulu	7.25	0.02	0.50	128.24	17.23	180.00	6.87	0.57	0.76	1.98	5.89
23.	T.Venkaiah	7.41	0.01	0.48	152.71	19.76	225.00	7.82	0.42	0.89	1.72	7.33
24.	A.AShok Reddy	6.92	0.02	0.48	91.03	10.34	310.00	5.04	0.47	0.46	2.45	8.72
	Mean	7.07	0.02	0.49	97.49	17.41	229.38	5.90	0.57	0.65	2.30	7.12

Table 1: Contd....

S. No.	Revenue Villages and name of the Farmer	pH (1:2.5)	EC (dSm ⁻¹)	Organic carbon (%)	N	P	K	S	Zn	Cu	Fe	Mn
					(kg ha ⁻¹)			(mg kg ⁻¹)				
IV. Sanjeevarayapuram												
25.	P.Prasad Kumar	7.29	0.07	0.59	122.64	19.64	245.00	9.00	0.63	0.64	3.13	6.29
26.	N.Reddappa	7.21	0.06	0.43	121.39	19.39	170.00	8.05	0.68	0.71	2.61	7.31
27.	S.Sankaraiah	6.58	0.08	0.51	96.31	17.63	285.00	4.38	0.42	0.77	2.72	7.00
28.	P.Uttaiah	6.93	0.11	0.57	74.67	9.45	155.00	4.93	0.39	0.52	1.09	5.28
29.	S.Balamurali	7.14	0.10	0.60	112.54	18.39	290.00	6.72	0.52	0.59	1.86	6.73
30.	T.Pandurangadu	7.38	0.05	0.48	83.46	21.33	205.00	6.82	0.81	0.62	2.54	7.59
31.	S.Chinnaswami Naidu	6.42	0.05	0.47	92.81	17.21	145.00	3.29	0.76	0.58	2.39	8.61
32.	T.Abdulla	6.86	0.12	0.53	88.29	16.42	165.00	4.00	0.51	0.50	1.93	5.29
	Mean	6.97	0.08	0.52	99.01	17.43	207.50	5.90	0.59	0.62	2.28	6.76
V. Sorakayalapalem												
33.	K.Pullaiiah	8.20	0.08	0.67	174.23	23.26	285.00	9.00	0.72	0.53	4.26	7.31
34.	G.Gangaraju	8.13	0.10	0.64	152.81	19.39	225.00	6.38	0.81	0.39	3.21	5.49
35.	T.Govindaiah	7.37	0.02	0.53	103.11	10.67	285.00	6.00	0.82	0.52	4.02	8.28
36.	C.Chenchuraju	7.54	0.09	0.63	149.28	13.28	290.00	4.38	0.54	0.51	3.67	9.30
37.	B.Gundaiah	8.09	0.01	0.58	163.67	21.64	205.00	7.05	0.39	0.46	2.13	7.71
38.	P.Venkataramana	8.11	0.04	0.71	178.13	20.32	305.00	7.38	0.52	0.43	2.86	6.34
39.	B.Sridhar	7.64	0.04	0.55	98.26	19.28	235.00	5.30	0.47	0.71	2.24	8.29
40.	C.Muneendhra Naidu	8.23	0.08	0.69	173.21	19.59	190.00	5.49	0.62	0.52	3.71	8.93
	Mean	7.91	0.05	0.62	149.09	18.42	252.50	6.37	0.61	0.51	3.26	7.71
VI. Gangireddipalli												
41.	Y.Sivareddy	7.39	0.02	0.64	92.67	9.73	185.00	6.80	0.77	0.42	4.38	10.61
42.	P.Khaseem Saheb	7.81	0.02	0.62	89.18	14.29	270.00	7.00	0.52	0.39	4.59	11.34
43.	T.Suresh Reddy	7.20	0.04	0.59	111.26	17.36	290.00	6.28	0.71	0.46	3.21	9.72
44.	S.Ramana Rao	7.63	0.03	0.62	128.35	17.73	190.00	6.21	0.86	0.59	2.88	8.28
45.	B.Ellaiah	8.11	0.08	0.67	171.86	21.32	205.00	9.82	0.76	0.56	2.63	8.59
46.	C.Gangireddy	8.04	0.07	0.68	134.39	21.56	210.00	8.00	0.72	0.38	3.71	12.33
47.	T.Chandhakanth Reddy	7.31	0.04	0.55	82.64	19.48	155.00	5.53	0.43	0.53	1.98	10.29
48.	A.Ramarao	7.19	0.02	0.71	96.76	18.53	285.00	4.00	0.51	0.45	2.73	8.34
	Mean	7.58	0.04	0.63	113.39	17.5	224.00	6.70	0.66	0.47	3.26	9.94

Table 1: Contd....

S. No.	Revenue Villages and name of the Farmer	pH (1:2.5)	EC (dSm ⁻¹)	Organic carbon (%)	N (kg ha ⁻¹)	P (kg ha ⁻¹)	K	S	Zn	Cu (mg kg ⁻¹)	Fe	Mn
VII C.Ramapuram												
49.	P.Sunil Kumar Reddy	7.34	0.04	0.51	91.34	16.37	190.00	5.69	0.82	0.32	4.02	11.31
50.	T.Babu Rao	7.29	0.05	0.43	65.39	14.28	245.00	5.00	0.54	0.21	3.29	12.61
51.	V.Krishnaiah	7.54	0.08	0.52	102.26	18.32	285.00	6.20	0.53	0.74	3.71	9.28
52.	A.Murali Krishna	7.86	0.08	0.64	54.93	21.03	285.00	6.89	0.21	1.21	4.11	6.34
53.	D.Munishankar	7.21	0.06	0.41	82.73	19.63	310.00	6.03	0.39	0.82	2.93	8.39
54.	E.Eswaraiah	8.03	0.07	0.62	98.29	20.93	305.00	8.00	0.51	0.76	1.28	10.21
55.	V.Nagaiah	8.01	0.04	0.58	92.13	21.91	290.00	7.52	0.38	0.42	1.73	9.34
56.	S.Nageswar Reddy	7.36	0.04	0.56	76.64	14.86	250.00	7.38	0.42	0.81	3.29	9.20
	Mean	7.58	0.05	0.53	82.96	18.42	270.00	6.59	0.48	0.66	3.05	9.59
VIII. Nethakuppam												
57.	P.Ravindhara Reddy	7.13	0.02	0.45	130.39	15.45	285.00	4.00	0.52	0.56	2.71	8.71
58.	C.Lakshmi Reddy	7.39	0.02	0.43	134.36	17.63	155.00	5.13	0.59	1.24	2.21	7.34
59.	B.Nagajuna	7.28	0.04	0.59	96.18	16.73	245.00	4.59	0.38	0.44	5.03	8.29
60.	A.Siddhaiah	7.26	0.01	0.47	129.44	9.29	155.00	3.86	0.26	0.49	4.82	5.42
61.	C.Krishna Reddy	7.84	0.02	0.53	82.02	12.34	170.00	6.00	0.51	1.05	4.71	10.11
62.	J.Prabhakar	7.32	0.05	0.50	111.09	18.67	190.00	5.43	0.39	1.11	3.28	9.32
63.	D.Balasubrahmanyam	7.61	0.02	0.49	86.37	17.32	230.00	7.60	0.54	0.89	1.86	9.86
64.	A. Raghavachari	7.34	0.04	0.42	122.34	18.73	170.00	6.80	0.50	0.76	2.64	7.34
	Mean	7.39	0.03	0.48	111.52	15.77	200.00	5.43	0.46	0.82	3.41	8.30
IX. Anupalli												
65.	B.Rangachari	8.03	0.11	0.56	138.21	22.03	225.00	9.70	1.01	1.24	4.23	7.14
66.	C.Sambasiva Reddy	8.19	0.09	0.59	123.62	23.19	285.00	9.00	1.04	0.49	3.21	11.39
67.	L.Kiran Kumar	7.34	0.08	0.63	94.28	15.24	310.00	6.55	0.92	0.56	4.71	10.28
68.	E.Chenna Reddy	7.83	0.10	0.58	96.31	17.32	225.00	5.52	0.90	0.72	2.36	8.29
69.	P.Ramakanth	8.29	0.10	0.70	129.10	20.21	300.00	6.80	0.71	0.91	1.82	5.23
70.	A.Kannaiah	7.64	0.04	0.54	83.26	18.69	255.00	4.03	0.70	0.93	1.93	9.71
71.	L.Niranjan	7.86	0.06	0.64	74.61	19.34	175.00	4.90	0.40	1.07	3.71	9.21
72.	H.Govindaraju	8.28	0.10	0.69	128.63	19.73	275.00	6.00	0.34	0.52	4.04	8.11
	Mean	7.93	0.08	0.61	108.50	19.45	256.25	6.56	0.75	0.81	3.25	8.68

Table 1: Contd....

S. No.	Revenue Villages and name of the Farmer	pH (1:2.5)	EC (dSm ⁻¹)	Organic carbon (%)	N ————— (kg ha ⁻¹)	P ————— (kg ha ⁻¹)	K —————	S —————	Zn —————	Cu (mg kg ⁻¹)	Fe —————	Mn —————
X	Kuppambadur											
73.	P.Sankaraiah	8.10	0.10	0.59	131.26	20.39	215.00	6.00	0.56	0.73	5.13	9.17
74.	L.Gopikrishna	8.18	0.11	0.48	154.18	21.05	250.00	7.18	0.39	0.64	4.71	12.71
75.	T.Venkanna	8.31	0.12	0.55	168.39	23.63	270.00	9.00	0.58	0.81	3.64	11.34
76.	B.Sivaiah	8.16	0.10	0.61	127.63	18.64	225.00	8.63	0.73	1.32	3.71	8.24
77.	J.Raghu	7.25	0.06	0.67	97.45	15.39	285.00	5.49	0.86	1.09	4.82	10.61
78.	B.Rajana	7.56	0.07	0.53	83.34	17.64	285.00	4.32	0.64	0.71	4.03	6.34
79.	E.Venkateswarulu	8.03	0.09	0.66	101.29	19.21	190.00	6.73	0.76	0.63	3.13	7.55
80.	C.Anilkumar	8.14	0.07	0.61	121.67	19.04	320.00	6.55	0.32	0.89	2.76	4.39
	Mean	7.97	0.09	0.59	123.13	19.37	255.00	6.74	0.61	0.85	3.99	8.79
	Overall	7.55	0.06	0.56	110.65	18.00	237.34	6.21	0.58	0.70	3.20	8.28