

**PROPERTIES OF RED SOILS OF AGROCLIMATIC ZONE-3  
(REGION-II) OF NORTH KARNATAKA**

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OCTOBER, 1994**



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(REGION-II) OF NORTH KARNATAKA**

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By  
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CERTIFICATE

This is to certify that the thesis entitled "**PROPERTIES OF RED SOILS OF AGROCLIMATIC ZONE-3 (REGION-II) OF NORTH KARNATAKA**" Submitted By **Mr. ASHOK S. ALUR**, for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SOIL SCIENCE** of the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

**DHARWAD**  
October, 1994

  
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*AFFECTIONATELY DEDICATED  
TO  
MY BELOVED PARENTS*

*Sri. SANGAPPA S. ALUR  
Smt. DANAMMA S. ALUR*

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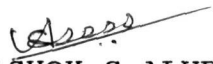
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**CHAPTER - I**

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**INTRODUCTION**

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## I. INTRODUCTION

Soils are the most vital component for providing fuel and fodder to meet the increasing requirements of ever growing population of 885 million in the country. The role of soils in agricultural production is more fundamental than any other factor. They need to be used rationally and conserved properly to ensure increased agricultural production on sustainable basis and to leave a better heritage for posterity (Sehgal *et al.*, 1993). The 1980's became the decade of awareness to the fact that the productivity of agricultural soils worldwide was in general on the decline and much of it occurred because of poor management and exploitative agriculture coupled with degradation. Since the soils are in general degrading at a faster rate than their natural regeneration it becomes important to protect them from degradation due to mismanagement and faulty land use. Different kinds of soils respond and behave distinctly for different management practices. Thus an exhaustive knowledge about rational utilization and management of these soils is necessary for efficient agricultural production.

The red soils occur in the tropical and subtropical conditions where rainfall varies from 600 to 4000 mm and mean annual temperature varies between 22 to 30°C with narrow differences between mean summer and winter soil temperatures, they occur at 50-2500 m above the mean sea level (MSL). Conceptually red soils are considered those which have hues of

5YR or redder in the soil series control sections (25-100 cm). These include red loams, red gravelly soils and red earths (latosolic or lateritic soils). Such soils are moderate to highly weathered, enriched in secondary form of iron, aluminium or both, poor in humus content, weakly to moderately depleted in bases and generally have clay enriched 'B' horizon.

The dominant red soils occurring in the tropical and subtropical regions of India, fall in eight agroecological regions (Nos. 7, 8, 12, 15, 17, 18, 19 and 20) established by the National Bureau of Soil Survey and Land use planning (NBSS & LUP).

The major physiographic regions in which red soil occurs are the North Eastern Hill ranges, Eastern Himalayas, Central highlands, Eastern plateau, the ghats, Deccan plateau and coastal plains (Sehgal, 1993). They are largely distributed in the intertropical region and most precisely in five agroeco systems namely semi-arid sub-humid, humid-perhumid coastal and islands. They are spread over an area of 59.6 m ha (Venkateshwaralu, 1987), whereas in Karnataka it constitutes about 35% of the total geographical area (Hegde *et al.*, 1987), bulk of which are in southern Karnataka. They are estimated to cover an area of 2.20 m ha in North Karnataka, 1153864 ha in zone-3 and are often associated with black soils. Red soils are generally derived from granites and schists of the Archean period. The other rock formations are sandstone, calcareous gneiss, basalts, shales, marine deposits and laterites (

Nagabhushan *et al.*, 1987) Red soils are light textured, shallow to medium in depth. Most of these soils have clay enriched, illuviated 'B' horizon with some amorphous materials (Shankaranarayana *et al.*, 1982) and have shown that red soils are developed as a result of transformation, translocation and illuviation leading to the release and dispersion of iron and aluminium hydroxides. These soils occur on gently-sloping to undulating geomorphic surfaces and are well drained within a range of excessively to moderately well drained conditions. Coarse and gravelly nature of soils results in low plant available waterholding capacity and restricted rooting depth. The soils are acidic, with low to medium cation exchange capacity and organic matter content. The chemical characteristics of these soils result from soil forming factors and processes, of which the dominating are rainfall, drainage, translocation and oxidation. Surface crusting is one of the problems which leads to increased runoff accompanied by soil erosion.

The farmers of Karnataka have identified long back red or dark-red soil (Kisumattara) for specific soil and land use. In Hyderabad Karnataka area, red soils are locally called as "Chalkas" or "Masubs" (Mehta, 1963). They are also called as Revazamins in Andhra Pradesh and 'Bhata' in MadhyaPradesh.

Detailed investigations have been conducted on these soils in different parts of the country. Kulkarni (1968) and

Parvatappa and Dorairaj (1972) studied profile characteristics and mineralogy of red soils of Mysore.

Rengasamy *et al.* (1978) documented the genesis, mineralogy and classification of ferruginous soils of south Karnataka. Krishnamurthy (1993) studied the properties, genesis and classification of red soils occurring in zone - 8 (Northern transitional zone) of north Karnataka. An estimated 1153864 ha of red soils occur in northern dry zone (Agroclimatic zone-3) in Karnataka, which are not studied extensively. Therefore, in order to understand the properties and probable genesis of these soils, a study was undertaken with the following objectives.

- 1) To study the physical, chemical and morphological properties of soils.
- 2) To know the probable genesis of these soils.
- 3) To classify these according to U.S. Taxonomy.

**CHAPTER - II**

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**REVIEW OF LITERATURE**

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## II. REVIEW OF LITERATURE

Rational utilization, proper management, conservation and improvement of soils is not possible without enlarging our knowledge about their genesis, geographical distribution properties and systematic classification. In Karnataka red soils are more extensive in southern part, however, they occupy considerable area in Northern dry zone in Karnataka, and they are only second to Black soils in extent. Although the soils of much of the humid tropics are superficially similar in appearance, careful study reveals a great diversity. These soils pose numerous management problems. In India, the research work done on red soils is not exhaustive and there is need for detailed investigation. Based on the available information the literature is reviewed under the following headings.

1. Genesis.
2. Morphology.
3. Physical and chemical properties.
4. Classification.
5. Use and management.

### 2.1. Genesis of Red soils

Dokuchayev appreciated the role of natural agencies of soil formation. He laid the principle of the geographicity of soil formation. Dokuchayev's teaching about soil formation is based on the following ideas. Soil is an independent natural body which is formed at the boundary between the lithosphere

and biosphere by the interactions of all the factors involved in soil formation, both live and dead. The composition and properties of a soil should be examined as they relate to their environment. The latter determines the dynamics and evolution of the soil. The fertility of a soil is its basic and specific property. It evolves with the soil and can be improved by rational soil use and by properly changing the process that develop the soils. When studying a soil as a natural body, the whole sequence down to the rock on which it is formed must be studied. If crust has been weathered by more than 3 m (as in the tropics and subtropics) it is necessary to consider the sequence within which water actively migrates and where the living organisms penetrate.

Horizon differentiation can be ascribed as additions, removals, transfers, and transformations within the soil system. These changes proceed simultaneously and the balance within the combination of changes govern the ultimate return of the soil. According to Van Schulyenborgh (1962) soil genesis is translocation of inorganic and or organic substances which proceed in a vertical sense. In humid climate one finds always down ward, and in arid climate an upward movement. Under the influence of these translocations horizon differentiation takes place in the substrate (Parent material). Since the soil is the combined product of parent material, climate, living organisms, relief and time, different combinations of these factors would produce different soils.

Evaluating the genesis of the soil, requires a good appreciation of the landscape relationships and specifically the geomorphoic evolution of the soil. Soil genetic processes may operate successively, simultaneously or separately with the product of one set of processes acting as the reactant for the next set. In the formation of red soil a common process is weathering resulting in the alteration of primary minerals and formation of secondary minerals.

The genesis of red soils in relation to the three important soil forming factors viz., climate, parent material and topography is dealt herewith.

#### 2.1.1. INFLUENCE OF CLIMATE ON GENESIS OF RED SOILS;

The role of climate in soil formation and soil distribution is very complicated because it renders various and numerous effects on these two phenomena. The climatic factor is so complex that no single numerical value can be assigned to a given climate. It is often considered to be a major factor determining the formation of great soil group. To be able to comprehend the effect of climate properly one should distinguish the dependencies between soil formation and climate. Climate include rainfall, temperature, humidity, wind, evapotranspiration, duration of sunshine and others. Of these constituents rainfall and temperature are very important which affect soil formation. Where monsoon type of climate prevails there is much seasonal variation in distribution of rainfall which in turn affects soil formation. Annual values

of precipitation provide a mean for rapid characterization of the moisture of region. Rainfall influences air moisture regime of soil and determines the character and extent of leaching to which a soil is subjected. High temperatures together with high rainfall in the wet tropics results in very intensive weathering.

Soil formation is also affected by the thermal energy of the sun's radiation, amount of rainfall or precipitation received. These factors regulate the thermal and water regimes of the soil stratum and the intensity of biological processes occurring in it. Thermal regime and water regimes are extremely important for soil formation. Thermal energy regulates the pattern and intensity of processes dependent on the environmental temperature. Direct correlation between an atmospheric climate and soils can only reflect some general geographic interrelations. They are frequently violated by numerous local factors which become important for a proper understanding of soil genesis and soil geography than the general factors. This is especially true of soils in the subtropical and tropical belts which never experience negative temperatures. Therefore in such areas both the atmospheric and the soil climates provide conditions for continuous rock weathering and soil formation. This was vividly seen in the conventional weathering coefficients obtained by multiplying the number of days with a temperature above freezing point by relative values of the degree of water dissociation. The values obtained by him indicate that rate of weathering and

soil formation in the tropical belt is three times greater than in the temperate and nine times greater than in the cold belts. Sometimes the differences are attributed only to the effect of temperature. But in as much as soil do not always maintain the same moisture content, the rates of weathering and soil formation are regulated not only by soil temperature but also by soil moisture. Karale *et al.* (1969) observed the formation of two distinct soil types under varied rainfall conditions over the same basaltic parent material. They observed very dark black soils under low rainfall (626-1250 mm) very dark greyish brown to black soils and acidic red soils under high rainfall (1620 mm). The difference in soil characteristics may be considered as the direct reflection of differential weathering reaction and developmental processes as conditioned by the amount of precipitation.

Studies by Gowaikar *et al.* (1976), indicate that basaltic complex requires very heavy rainfall while granite genesis material requires less rainfall. They found that granite gneiss on weathering give rise to predominantly Kaolinite minerals with no traces of illite.

Rengasamy *et al.* (1978) studied the genesis of ferruginous soils of Eastern Mysore Plateau. In the Koppali and Royalpad series of the Northern Karnataka and in Nandi series of South Karnataka, intensive weathering has led to kaolinization and adsorption of iron compounds on the Kaolinite. But due to insufficient accumulation of iron

compounds, either relative or absolute granulation has not resulted. The absence of high water table in the profile has led to the formation of red soil material in these profiles without any ferruginous gravel layer or pallid zone.

The dominance of kaolinite in the clay and silt fractions and its occurrence in the coarser fractions of the soils in various proportions clearly indicated that kaolinization was the major process operative during the weathering of granite gneiss. Well drained condition favours kaolinization, but the present day warm semiarid climatic conditions surrounding areas of Bangalore is not severe enough for intense kaolinization ( Bhattacharya and Ghosh, 1990).

Krishnamurthy (1993) studied the role of climate in the genesis of red soil of northern Karnataka. According to him climate has a secondary role in the pedogenesis of soils . High rainfall at Shyadambi site has resulted in deeper and intense weathering. The low CEC in relation to high clay content was the best index. higher rainfall was also reflected in higher organic carbon,  $\text{BaCl}_2$ -TEA acidity and strongly acidic pH in Shyadambi pedon in particular and other soils of Dharwad schist compared to Manvi and Badami pedons.

#### 2.1.2. TOPOGRAPHY AS A FACTOR OF SOIL GENESIS

Relief, unlike climate, vegetation, soil forming rock does not materially participate in the soil formation. It does not alter any qualitative parameters of soils or their composition. The relief or topography only regulates the

inflow of thermal energy, atmospheric and ground water to soils, thus affecting the distribution of vegetation and animals. Topography controls the distribution of soil in the landscape to the extent that soils of markedly contrasting morphogenesis and properties can merge laterally with one another. The topography influences both external and internal drainage conditions, differential transport of eroded material, leaching and translocation which ultimately determines soil characteristics. At the same time, the effects rendered on the topography by thermal, water and wind energy lead to denudation of soils, i.e, their erosion and deflation both natural and anthropogenic due to ploughing and other methods of tillage. Finally continuous development of the earths surface relief determines the evolution of soil and soil cover. The role of microrelief in the formation of diverse types of soil in close proximity has been shown in some localities of India (Raychaudhuri ., 1963). The occurrence of diverse type of soils, such as red or lateritic on the one extreme of a soil slope and black soil on the other extreme, is not uncommon in tropics and subtropics ( Mohr and Van Baren, 1954).

Biswas and Gawande (1962) observed formation of four different kinds of soils viz., red earth, yellow earth, brown earth and black soil in the toposequence. Red earth occupied highest position of the slope, deep black soil was confined to depressions, brown earth and yellow earth occupied intermediate position on the land scape in the Chatishgarh basin of Madhya pradesh Biswas *et al.* (1966) in their studies on catenary soils

on granite gneissic parent rock in Kurnool district found that down the slope, as drainage intensity lessens soil color gradually changed from dark reddish brown to very dark grey and texture from sandy clay loam to clay. Chemical composition also changed  $\text{SiO}_2$  content increased and Al, Mn, Ca and Mg levels increased. Illite was found to be the dominant factor in development of the sequence. Krishnamurthy (1993), studied the soil physiography relationships in eleven red soil pedons of northern Karnataka. According to him in the undulating to rolling landscape of Dharwad area, there exists a clear relationship between soil and physiography. The soils were shallow to moderately deep in the upland and deep to very deep in the midland situation at all the sites. Erosion and redistribution of weathered materials, have been responsible for the observed properties. The content of finer constituents, especially the clay particles is higher in the pedons situated in the lower element of the landscape ( Biswas *et al.*, 1966). Translocation of clay vertically downward in the profile even in upland soils was noticed. In granitic landscape of Bijapur district the soils with argillic horizons both on mesas and uplands ( RhodustalFs) and on pediments (HaplustalFs) (NBSS and LUP; 1982) Both the upland and midland pedons present in an AP-Bt-BC-C sequence, where as in Hunashikatti pedon a BW horizon was seen both in upland and lowland situations. Rudramurthy (1994) who studied five pairs of associated red and black soils from North Karnataka found that in Bidar, Bheemarayangudi, and Mantagani sites, both black

and red soils are derived from the same rock but due to variation in drainage as conditioned by topography, deeper solum of the black soil suggested that they have been located on depositional surfaces where as red soils have occupied erosional surfaces. The topographic differences were subtle and not as clear as in a catenary association. The differences in degrees of calcareousness, salinity levels Free  $\text{Fe}_2\text{O}_3$  content clay to CEC ratios between red and black soils in each site pointed out that red soils were better leached than black soils.

#### 2.1.3. Parent material as a factor of genesis

Rocks and products of their weathering and redeposition serve as the mineral basis, which comprises upto 80-97 per cent of al soil mass in soils. That is why soils inherit their properties to a great extent from the mineral part of their parent rock. Their mineralogical and chemical compositions. If such inheritance is not exhibited i.e, the particular soils reveals a mineralogical, chemical and mechanical composition of its own, different from that in the rock, the latter should be regarded not as parent but as the basement rock. Under such situation, it is stressed that there is no genetic relationship between the rock and the soil terrain. This differentiation of rocks as soil forming and basement ones is important in determining the mineralogical and chemical composition of soils and for proper treatment of their genesis. These two notions are frequently confused and consequently the genesis of some tropical soils is still

unclear and disputable. The role of soil forming rocks in soil formation is many sided. In the first place, rocks of different origin, different petrographic and mineralogical composition render different effects on the formation of secondary clay minerals of soils and on their chemical composition. In the second place the properties and structure of parent rocks are reflected in the morphological and physical properties of soils such as their thickness, consistency, texture etc.

Jenny (1941) defined parent material as the initial state of soil system and thus avoid special reference to the strata below the soil which might or might not be the parent material. Parent material influences the morphological, physical, chemical, physico-chemical and mineralogical properties of soil.

Roy and Landey (1962) studied the three red and laterite profiles developed on pink shales of Cuddappa system in Mand watershed of Raigarh and found that iron concretion embedded increased in number with depth. It was found that  $\text{Fe}_2\text{O}_3$  and  $\text{Al}_2\text{O}_3$  content in the profiles increased with depth and  $\text{SiO}_2$  content remained unchanged. These gave rise to soils predominantly rich in illite clay minerals with some kaolinite.

Manickam (1965) observed that the difference in parent rock composition in association with climate, vegetation and slope produced different kinds of soil profile in Nilgiris.

The varied nature of the soils indicated that the characteristics of soils were predominated by parent rock.

Tamhane and Karale (1967) observed the occurrence of four different kinds of soils such as red, black, brown and laterite soil over the basaltic parent material under varied climate and topography.

Parvatappa *et al.* (1964) studied eleven red soil profiles from different parts of Karnataka State. Most of those soils were formed from granite gneiss except in one case where it was derived from chlorite schists. These soils occurred at medium high elevation and semi arid conditions. They were found to be still in intermediate stage of weathering and have attained equilibrium under the present climatological conditions of the area. There were not much differences in soil characteristics ascribable to difference in parent material.

Rengasamy *et al.* (1978) who studied ferruginous soils of Eastern Mysore plateau on two different land systems formed on acidic peninsular gneiss found that the soils of older and fairly smooth landscape are composed of colluvium over truncated laterite profiles, with a gravel layer and a prominent kaolin layer over weathered rock. They found that the soils show an accumulation of pedogenic haematite grains in the sand fraction, and have considerable kaolinite and amorphous ferri-alumino silicate minerals in the clays.

**Th. 3877**

Red soils of Orissa developed on charnokite and khondalite of rocks of the eastern ghat region. Acidic reaction and high permeability have lead to the dominance of kaolinite in the soil from semiliguda while a higher proportion of potash feldspar and mica are respnsible for dominance of illite in Pharbani soils ( Sahu *et al*, 1983).

Bhattacharya and Ghosh (1990) studied the genesis of Alfisol profile in Konankunte village of Karnataka in relation to parent material and climate.

The dominance of kaolinite in the clay and silt fractions and its occurance in the coarser fragments of the soils in various proportions clearly indicated that kaolinization was the major pedogenic process operative during the weathering of the granite gneiss.

Sahu *et al* (1990) studied the morphology, genesis mineralogy and classification of soils of northern plateau zone of Orissa. Presence of Limenite and limonite to the extent of 41 per cent in the sukati pedon explains the soils to have been formed on iron ore series parent rock.

Krishnamurthy (1993) recorded the influence of parent material in the genesis of red soils. In the soils of Dharwad rock system , the abundance of coarse fragments, resistant to weathering (quartzites) were seen as remnants. The solum of Chatra, Koonabevu, and Chalagere pedons were influenced by quartzitic material underlain by soft, weatherd chlorite schist

relatively free from quartzite. Shyadambi pedon was observed to be free from the influence of quartzite and as a result more intense and deep weathering was observed. Higher clay content and clay movement was also seen when compared to other soils of Dharwad schist.

## 2.2. Morphology

A thorough knowledge of morphological features is necessary in order to place the soil in its correct position in the classification system.

### 2.2.1. Soil colour and structure

Conceptually red soils are considered those which have hues of 5 YR or redder in the series control section (25-100 cm). These include red loams, red gravelly soils and red earths (latosolic or lateritic soils).

The term red and yellow refer to the colour of the subsurface horizon, which has a hue that is either yellow with high chroma or red. The two colours indicate the presence of a fair amount of ferric iron, which as the term implies is indicative of good drainage conditions (Bennemma; 1963).

The soils developed under low rainfalls are very dark greyish brown to black and alkaline in reaction and those developed under high rainfall are red in colour (Karale *et al.*, 1969).

According to Shankaranarayana and Sarma (1982), red soils have well marked horizons of clay enrichment that are

easily describable in the field. Variations in texture, depth, colour and clay mineralogy results from relief and drainage differences. They occur on gently sloping to undulating surfaces and are excessively to moderately well drained. These soils have weak granular blocky to prismatic B horizons and subangular blocky 'C' horizons.

The soils vary from red to yellow in colour which is due to coating of ferric oxides on soil particles. It is red when the ferric oxides occur as haematite and yellow when ferric oxides occur in hydrated form (limonite) (Reddy *et al.*, 1990).

#### 2.2.2. Development of argillic horizon

Argillation is an important process in arid and semi arid lands in the formation of an argillic horizon, and it is evident in relatively older mature soils and comprises of mobilization, transportation and accumulation of fine clay (less than  $0.2 \mu\text{m}$ ) particles. The process of argillation is the result of sudden wetting of dry soil, causing an appreciable rise in pH and temporary mobilization of clay. The mobilized clay is transported over a short distance by percolating water and accumulates on ped surfaces of a slightly deeper horizon as pores get dried because of low precipitation (Buringh, 1970).

Red soils are shallow to medium in depth, most of these soils have clay enriched, illuviated 'B' horizon with some amorphous clay materials as a result of transformation

translocation and illuviation leading to the release and dispersion of iron and aluminium hydroxides.

An argillic horizon will have higher clay content than overlying horizons. But this alone is not the criteria for defining argillic horizon. Weathering might account for the increase in fine clay in some argillic horizon (Nikiforoff, 1937).

However, argillic horizons, will have a higher ratio of fine (less than  $0.2 \mu\text{m}$ ) to total clay than other horizons of the pedon. Yarilova 1963, observed that the illuvial clay is strongly oriented on the peds of 'B' horizon while *in situ* weathered clay occurred in the form of small flakes and chips scattered at random. The presence of clay skins can be taken as good indication of the movement of clay. The absence of the same does not disprove the development of an argillic horizon, since the clay skins are not permanent in nature.

Buol and Hole (1959) pointed out that clay skins were likely to be truncated during the process of soil expansion and contraction.

Smith and Buol (1968) concluded that both clay formation *in situ* and enrichment by illuvial fine clay are responsible for development of argillic horizon in soils of arid and semiarid regions.

Clay migration and subsequent clay coatings have been described in a variety of soils including planosols. Gray

brown podzolic soils of temperate region (Buol and Hole, 1959), Brown podzolic and latasolic soils of the tropics. However, clay migration assumed greater importance in the semiarid region because of shallow depth at which clay concretion occurs.

Free drainage may promote the formation of textural 'B' horizon. Hallsworth (1963) from his study on the factors affecting the movement of clay opined that grade of sand among other factors, also affects migration. In coarse sands and gravels, considerable movement of clay can occur mainly through mechanical transport.

The chemical and mineralogical nature of the clay in clay cutans, is found to be different from that of clay in the B horizon. Buol and Hole (1959) reported that clay skins show relatively high contents of N (0.11 per cent), C (1.84 per cent) clay (87.4 per cent), free iron 2.76 per cent as compared with bulk samples from B<sub>3</sub> horizon (0.029 per cent N, 0.43 per cent C, 24.3 per cent sand 1.13 per cent free iron). X-ray diffraction patterns showed that the clay in the bulk samples obtained slightly more chlorite and slightly less vermiculite than the clay of clay skin.

Mackeague and St. Arnaud (1969), found that clay cutans will have much higher organic matter, clay, phosphorus, manganese and iron than bulk of 'Bt' horizon.

An important process in red soils is clay translocation leading to the formation of an argillic horizon.

The conditions promoting the formation of an argillic horizon is given by Eswaran and Sys (1974).

Raghumohan and Bhonsle (1993) studied six Alfisol pedons covering representative soils of Goa, Karnataka and Pondichery, aggregate analysis of the epipedons and argillic horizon have shown that all Alfisols have a structurally stable clay rich argillic or subsurface horizon.

Krishnamurthy (1993) reported that, the important pedogenic process in red soils is illuviation of clay in majority of the pedons, out of eleven red soil pedons from different parts of North Karnataka taken for the study. Illuviation was favoured by the porous light textured surface horizons in all the pedons. The parent rock of all the soils have enough clay for translocation. The conditions favourable for the translocation of clay and accumulation of clay in the subsurface are enumerated in the Soil Taxonomy (Soil Survey Staff, 1975). The translocation of clay was evidenced by presence of clay cutans on ped faces. They were mostly thin, patchy, and occurred as sand bridges and along root channels. The morphological expression was often not commensurate with the magnitude of clay increased between eluvial and illuvial horizons. This was largely because of lack of good structure development in the subsurface horizons due to high gravel content and high free iron content. The distribution of clay and fine clay testified to the movement of clay in these soils. Further in argillic horizons that have few or no clay

skins , the ratio of fine to total clay was greater in argillic horizon than in horizons above it (Soil Survey Staff, 1975). This was the case in Shyadambi pedon where clay skins were not evident. The lack of clay skins in the pedon may be due to turbation due to biological activity and high iron oxides which might have masked the features. A relatively thicker argillic horizon signified stability of landscape and greater age among the soils from Dharwad schists.

### 2.3. Physical and Chemical Properties

Raychaudhuri (1941) recognised broad morphological types of red soils. (i) Red loams, characterised by argillaceous soils with cloddy structure and a little concretionary material and (ii) red earth, with loose top soil, friable but rich in secondary concretions as a consequence of sesquioxide rich clay.

Sinha *et al.* (1962) studied the red soils in Ranchi district of Bihar. The morphological and chemical properties of soil profiles were drastically correlated with topo sequence. Down the slope, depth increased, texture became heaviest, structure changed from single grained to blocky, pH changed from acidic to neutral and organic carbon and nitrogen contents increased.

Parvatappa and Raj (1968) studied the characteristics of red soil and their productivity and concluded that red soils in Mysore state occurred at medium high elevation and were developed under semiarid conditions. The parent rock was found

to be granite gneiss in most cases and chlorite schist in one case. Highly significant interrelations among physical properties the pore space, hygroscopic moisture holding capacity, moisture equivalent and sticky point were obtained. The amount of clay influenced physical and chemical properties. Negative significant correlations of clay were obtained with coarse sand, fine sand and silica-sesquioxide ratio. Iron oxide indicated greater mobility than aluminium. Silica sesquioxide ratio and silica alumina ratio indicated that nature of clay mineral was kaolinite. Anjaneyalu and Raychaudhuri (1964) reported the characteristics of several red soil profiles from Mandya district. The texture varied from sandy loam to clay in the surface. The subsoil was more clayey. The soils were acidic but approached neutrality in the lower horizons. They had low base exchange capacity. Calcium and magnesium were the dominant cations. Soluble salts Ca, P (total and available) K, Mg, and organic carbon were low. Cation exchange capacity of clay fraction ranged from 25 to 42 me/100 g clay. X-ray analysis indicated that the clay fraction contained a mixture of kaolinite and illite with traces of montmorillonite. Eleven red soil profiles collected from different areas in Karnataka were studied by Parvatappa and Raj (1972). The total iron oxide, free iron oxide, aluminium and magnesium increased with depth in most of the profiles. Iron oxides had greater mobility than alumina. Silica/Sesquioxides and silica/alumina ratios indicated that the clay was be kaolinite. The soils were neutral in most of the cases and the

the pH was correlated with the available phosphorous and iron oxide.

Govindarajan and Murthy (1971) studied four important soil groups namely reddish brown laterite, red mediteranian, tropical ferruginous soils and latosols. The tropical ferruginous soils reveal textural differentiation. The A horizon was of sandy clay loam texture, crumb structured and very friable and graded to thick, B horizon of gravelly clay loam to clay texture and blocky structure. pH was acidic (5.3 -5.6) and base saturation was low. The B horizon consisted of abundant iron and managanese concretions and horizons below an ABC profiles, and A horizon of sandy loam texture and crumb structure, low in organic matter grading to deep, campact but permeable B horizon, of argillaceous material of medium CEC (4.9 -9.6 meq/100 g of soil) with blocky structure. The textural gradient was not very strong but clay films on structure surface was well expressed. The pH ranged from 6.4 - 6.8 in subsoil.

A pedogenic study was undertaken to characterise and classify some associated soils of Regional Research Station Dharwad, by Nagalikaar (1979). The soils have been developed on Dharwad's and Kaladagi geological formations. The redder hues in red soil denote intense weathering and higher chroma associated with free drainage. The red soil have agillic horizon developed as a result of illuviation of clay; calcium is the dominant exchangeable cation followed by Mg, Na and K.

Anonymous (1982) recorded the water retention of tropical red and lateritic soils varying in texture at different depths in the profile for some bench mark soils like Jamakhandi series ( Typic paleustalf) in Karnataka, Tyamagondalu series ( oxic paleu stalf) in Karnataka, Hattiapathor series ( Typic achraquaf) in Bihar and Bhubaneshwar series (Typic Haplustalf) in Orissa. Water retention increased in all cases to a great extent down the profile both at 33 Kpa and 1500 Kpa soil water retention. Bulk density of Jamakhandi series varied from  $1.52 \text{ g cm}^{-3}$  (0-16 cm) to  $1.68 \text{ g cm}^{-3}$  (16-40 ) and the moisture retention from 14.5 per cent (  $1/3$  bar ) to 5.7 per cent ( 15 bar)for the first depth ( 0-16 cm) where as it varied from 21.7 per cent (  $1/3$  bar) to 9.8 pr cent ( 15 bar) for the second depth ( 16-40 cm).

According to Shankaranarayana and Sarma (1982) red soils have well marked horizons of clay enrichment that are easily describable in the field. The soils are strongly acidic to moderately alkaline in reaction; cation exchange capacity and organic carbon content varies from low to medium. Available water holding capacity of red soil profiles varies from 5-15 cm. In a red soil profile of Bhubaneshwar, water retention at 33 kPa varied from 14.5 to 16.9 per cent which increased to 27.2 per cent at 47.7 cm depth. Moisture retention at 1500 kPa soil water tension varied from 4.2 per cent in Bangalore to 5.6 at Bhubaneshwar. At greater depth moisture percentage increased by 12.5 to 18.4 per cent

Bhubaneswar series showed moisture retention of 5.6 per cent at 0.13 cm and 8.8 per cent at 50-78 cm depth ( Panda, 1990).

Sahu *et al.* (1990) studied the red soils of northern plateau zone of Orissa. The content of clay increased downwards in profiles with simultaneous decrease in sand content indicating well drained conditions. There was a gradual decrease of organic matter content from the surface downwards indicating the maturity of the profile. The free iron oxide content is appreciable, ranging from 4.28 to 17.74 per cent.

#### 2.4 Classification

Soil formation depends upon the combined and simultaneous effects of all pedogenic factors. Their combination provides the environment for soil formation, while the actual manifestations of soil formation are regulated by particular combinations of these factors. The composition and properties of soils reflect the environment in which these soils were formed. Hence like any other natural formations, soils need to be systematized and classified. It has been said that classification is the mirror which reflects the present state of knowledge.

The general task of classification is to group things in such an order as to enable us to remember and understand the things which govern them. According to the first natural soil classification of Dokuchayev of Russian school soils were independent, natural bodies possess properties reflecting the effect of local and zonal soil forming factors.

Coffey of U.S.D.A. classified soils in 1912 into five classes on the basis of properties. Marbut Baldwin Kelley and Throp classified the soils based on the genesis or on the properties of so called virgin soils.

A new system of classification was presented by Soil Survey Staff (1975) and is being modified since. According to the latest revision of system (Soil Survey Staff, 1992) soils are classified into eleven orders based on their properties. Each order is further divided into suborders, great groups, subgroups, families and series.

Two International Committees, the International Committee on soils with low activity clays (ICOMLAC) and International Committee in oxisols (ICOMOX) based on their discussions and with more recent studies on these soils provided the first major conceptual change in Soil Taxonomy since its publication in 1975. Emphasis was given to oxic horizon than argillic horizon and any soil with an oxic horizon is now considered as an Oxisol. Consequently the charge characteristics and the colloid composition were emphasized because there were many covarying properties. However, clay translocation as an important pedogenetic process was not ignored. In soils with high activity clays, the presence of an argillic horizon is considered at the order suborder or great group levels. In low activity clays (LAC) it is considered at great group level.

Classification of red soils of India was initiated by Raychaudhuri (1962). Govindarajan and Datta Biswas (1968) classified red loamy soils as PaleustalFs, RhodustalFs and HaplustalFs and red sandy soils as RhodustalFs and HaplustalFs.

Parvatappa (1964) classified red soils of Mysore as red loam and red soils with  $\text{CaCO}_3$  concretion. He classified these soils under Ultisols.

Govindarajan and Datta Biswas (1968) identified red soils of Muchakund basin in Korapat districts of Orissa as latosols of high base status. Further they classified red and lateritic soils of Muchakund basin of Andrapradesh and Madhyapradesh as Udic HaplustalFs, Ultic PaleustalFs and Ultic RhodustalFs.

The soils of hill districts of Assam was classified as PaleustalFs, Haplustalf, hapludult and Paledult on the basis of their morphology and physico chemical properties (Chakravathy and Barua, 1983).

Murthy *et al.* (1982) classified red and lateritic soils of Karnataka, as PaleustalFs (Tyamagondalu series), HaplustalFs (Vijayapur series) and as RhodulstalFs (Channasandra series).

Zende (1987) classified the soils of Nagaland in relation to physiography. The dominant soils are (i) fine loamy typic hapludults on very steep side slopes of high hills. (ii) Loamy skeletal Typic Udorthents on narrow ridges of high

hills (iii) loamy skeletal, Typic Hapludults on broad ridges of hills and paleudults on steep slopes of high hills and very low hills.

Eswaran (1988) defined red soils as "those soils that have a hue of 5YR or redder, and have a CEC of (1 N  $\text{NH}_4\text{OAC}$  at pH 7) 24 meq per 100 g clay or less, or an CEC of 18 meq per 100 g clay or less. In addition they have less than 10 per cent weatherable minerals in the fine sand fraction. They may have an argillic or oxic horizon but do not have a cambic horizon, and they have a thermic, isothermic or warmer isotemperature regime"

Red and lateritic soils are classified under the orders of Entisols, Inceptisols, Alfisols and Ultisols, At the great group level they qualify for Troporthents and Ustorthents (within Entisols), Dystrypepts, Ustrophepts, Humitrophepts and Ustochrepts. Great groups of Paleustalfs, Haplustalfs, Plinthustalfs, Rhodustalfs, Kandistalfs, Kanhaplustalfs, Rhodualfs, Hapludalfs, and Paleudalfs, (within Alfisols) and Paleustalsts, Hapustults, Pelehumults and Haplohumults (within Ultisols). The suborder under Kondi and Kanaplo great groups and Kandic sub groups are the low activity clay soil (Soil Survey Staff, 1975; 1992).

Sahu *et al.* (1990) studied three pedons formed on highly weathered materials and iron ore series rocks in the northern plateau zone of Orissa and classified them according to U.S. Soil Taxonomy. Shamakuntha and Sukati pedons situated

on bonded pediments have argillic horizon and are placed under Haplustalfs and Ultic Paleustalfs respectively. The Joshipur pedon formed on a moderately sloping land is placed under Plinthic Eustrustox.

Krishnamurthy (1993) classified eleven pedons according to USDA taxonomy. All the pedons except Hunashikatti (upland and midland) belong to order Alfisols, since all had an argillic horizon, whereas Hunashikatti upland and midland pedons to Inceptisol because of the absence of argillic horizon. At suborder level these pedons were put under Ochrept, whereas remaining pedons were put under Ustalfs as they remain dry for considerable periods in a year. At great group level, the Manvi, Chatra (upland), Koonbevu (Midland) and Chalagere (midland) were classified as Haplustalfs; Badami, Chatra (midland), Koonbevu (upland) and Chalagere (upland) were classified as Rhodustalfs; and Shyadambi as Paleustalfs.

Rudramurthy (1994) classified five pairs of associated red and black pedons as per U.S.D.A. soil taxonomy. B'Gudi, Raichur and Dharwad red pedons were classified as Alfisols as they possessed argillic horizon. Mantagani and Bidar red pedons were classified as Inceptisols (Ustropepts).

#### 2.5. Use and management

Nowadays the soils are associated with declining productivity reduced profitability and threats to animal, human and soil health. The rationale of soil survey interpretations is that the soils classified in the same taxa have a common

response to management practices. Smith and Buol (1968) indicated that for a particular kind of soil where ever it exists, similar management practices can be adopted if due consideration is given to climatic differences.

Red and lateritic sandy loam soils which are highly percolative and have problem of water retention can be improved by raising the bulk density by  $0.2 \text{ g cm}^{-2}$  by making four passes of 800 Kg roller. Such a treatment reduced the percolation rate from 2.9 to  $1.1 \text{ cm hr}^{-1}$  in Kharagapur soils (Ghildyal and Satyanarayana, 1965).

El-Swaify et al. (1987) attributed the lack of consistent success in managing red soils under rainfed condition to several physical factors as discussed below. Red soils generally possess inherently low water retention characteristics because of their particle size make up and mineralogical composition. This is often compounded by the shallow depth of the soil zone available for water storage. Lack of water storage combined with mechanical impedance problems in these hardening soils limit crop root proliferation. Improvements in medium characteristics as a result of tillage are only temporary because of the lack of structural stability. The structural instability and subsequent frequent failures in land surface configurations lead to reduction in surface roughness (useful for maximising infiltration) and enhancement of surface sealing and crusting. (Westeyn 1983). These on the one hand induce excessive run off

even early in the season and, on the other, directly affect seedling emergence. Direct effects on crops are more drastic with small seed crops such as pearl millet, finger millet and sorghum. Localized droughts are also very likely in the seed environment, i.e. in ridges or beds into which water entry by infiltration is restricted by surface sealing. Crusted soil surface are also presumed to be prone to increased evaporating water loss.

In contrast to black soil, rainfed cultivation of red soils in the semiarid tropic is practiced only during rainy seasons. The growth period for the sequential cropping is extended into the post rainy seasons where water is available for supplemental irrigation. The main traditional crops include sorghum, pearl millet, finger millet, groundnut, pigeonpea, cotton, castor, greengram and black gram (El-Swaify *et al.*, 1987). These are grown as sole crops, in discrete mixtures or as inter crops.

Soil crust management is a serious concern for improving seedling emergence and crop stand establishment in case of rainfed red soils. Working the soil with a rolling crust breaker with spikes mounted at precalculated positions can substantially improve seed emergence for susceptible seeds when available soil moisture is not a limitation to growth (Kazzamann *et al.* 1983). Working the soil with spike toothed harrow of the crust is formed within one or two days of seeding, seeding on the ridge side, which is less prone to

crust formation and mulching the seedlings with organic residues to minimise the beating action of raindrops (Hadimani *et al.*, 1982).

According to the results obtained by investigations of El-swaify *et al.*, 1987, on hydrologic studies at ICRISAT, soil and water losses are caused by high intensity rains, sloping lands and crusting nature of soils. The traditional farming systems have shown that, of the total rainfall potentially available an average of about 26 per cent is lost through run off, 33 per cent through deep percolation and only the balance 41 per cent is utilized for evapotranspiration by crops. A promising approach for conserving soil and water is the construction of graded bunds. Contour bunds for low rainfall areas, and graded bunds for medium deep soils with seasonal rainfall more than 700 mm, deep red soils are suitable for border-strip layout (Hegde *et al.*, 1987).

Incorporation of crop residue in red soils helps in improving the fertility status and soil physical condition (Pathak, 1984).

Red soils are highly deficient in nitrogen and phosphorous. Zinc becomes limiting at higher production levels, potassium is less than adequate where kaolinite is the dominant clay mineral. The critical values of soil fertility below which responses to added fertilizer could be economical or 70 ppm for exchangeable  $K_2O$  ( $NH_4OAC$  extraction method) 48 ppm for  $P_2O_5$  ( $Na_2CO_3$  fusion method) and 0.83 ppm (DTPA extraction

method) . . . Cereals respond to both N and P, oilseeds more to N and legumes more to P. Synergism is conspicuous between N and P for cereals. Placement improves the efficiency of fertilizer use because subsoils are generally infertile. Split application of nitrogen is necessary to cover the risk of aberrant weather, Organic residue incorporation improves and sustains crop production (Venkateshwaralu 1987).

**CHAPTER - III**

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**MATERIAL AND METHODS**

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### III MATERIAL AND METHODS

#### 3.1. Location of study sites

Northern dry zone consists of eleven taluks of Bijapur district, eight taluks of Bellary, six taluks of Raichur, five taluks of Belgaum and five taluks of Dharwad district.

The total geographical area of this zone is 4,786,640 hectares and total sown area is 3,466,048 hectares. The area under red soils in this region is 1,153,864 ha.

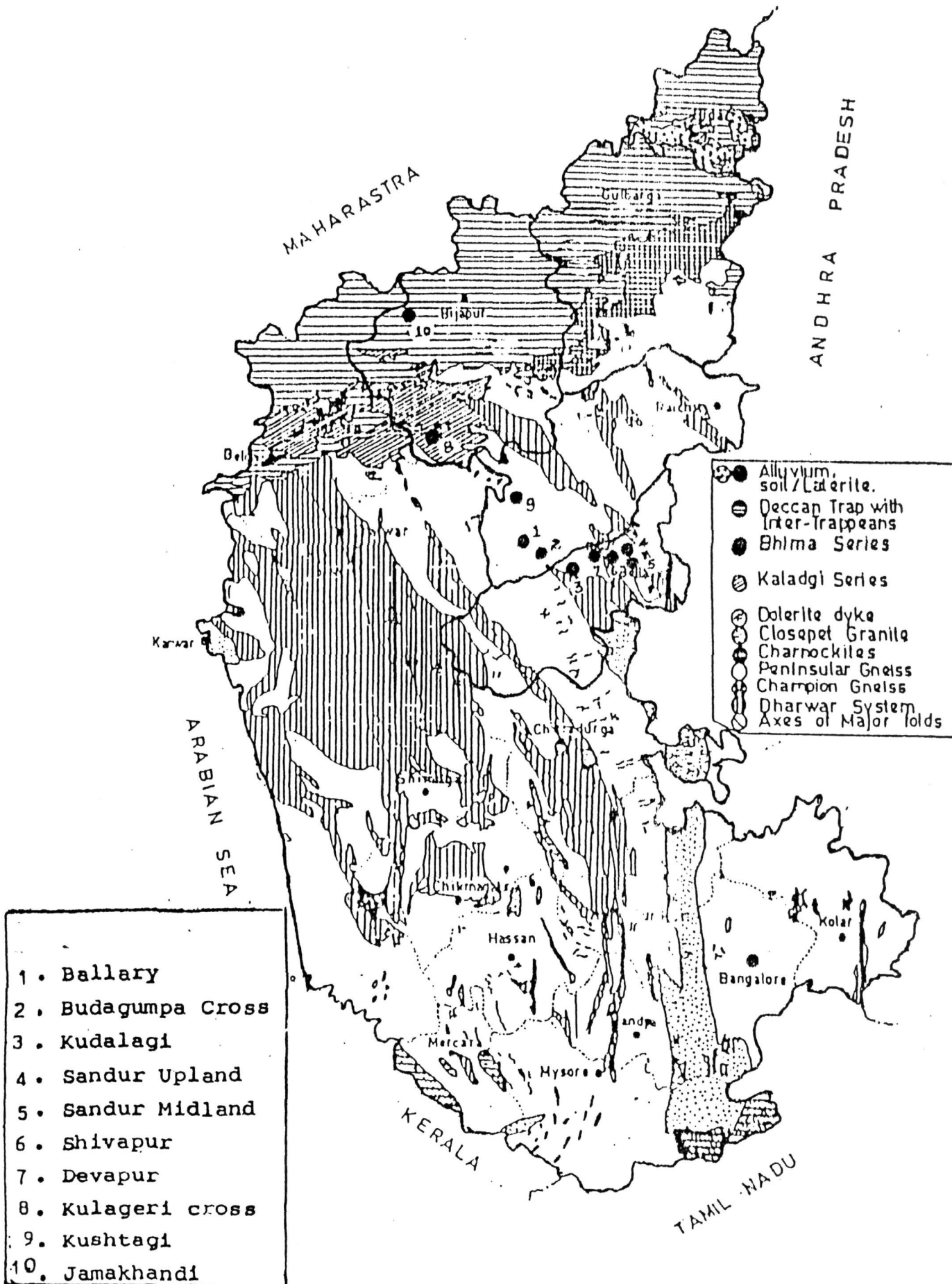
Ten red soil pedons from different locations in Northern dry zone (Zone 3) were selected for the study. The particulars of which are presented in Table 1 and locations are shown on map in figure-I. The general description of the area is given below.

##### 3.1.1. Physiography, relief and drainage

Bellary and Budagumpa are characterised by gently undulating to rolling mid upland type of physiography. The main river system draining this area is Tungabhadra which flows towards east and join Bay of Bengal.

In Timmapura, Shivapur, Devapur, Sandur upland and midland, the physiography ranges from very gently undulating to rolling, mid-upland to undulating upland. River Chikkahagari a tributary of Tungabhadra river drain this area.

The physiography of Kulageri, Kushtagi and Jamakhandi is characterised by undulating to plain land scape with broad



- Alluvium, soil / Laterite.
- ⊖ Deccan Trap with Inter-Trappeans
- Bhilma Series
- ⊙ Kaladgi Series
- ⊙ Dolerite dyke
- ⊙ Closopep Granite
- ⊙ Charnockites
- ⊙ Peninsular Gneiss
- ⊙ Champion Gneiss
- ⊙ Dharwar System
- ⊙ Axes of Major folds

1. Ballary
2. Budagumpa Cross
3. Kudalagi
4. Sandur Upland
5. Sandur Midland
6. Shivapur
7. Devapur
8. Kulageri cross
9. Kushtagi
10. Jamakhandi

Fig.1. MAP SHOWING LOCATION AND GEOLOGY OF THE SITES STUDIED

Table 1. Location of study sites

Pedons	Location	
	East longitude	North latitude
Ballary	76° 18'	15° 26'
Budagumpa	76° 19'	15° 25'
Timmapura	76° 36'	15° 23'
Sandur upland	76° 30'	15° 1'
Sandur midland	76° 33'	15° 2'
Shivapur	76° 15'	14° 20'
Devapur	74° 22'	14° 50'
Kulageri	75° 29'	15° 50'
Kushtagi	76° 11'	15° 49'
Jamakhandi	75° 17'	16° 32'

based valleys. The river systems draining this area include Malaprabha and Krishna, both are east flowing. All the soils under study are well drained.

### 3.1.2. Geology

The important rock formations of the region include granite, granite gneiss, Deccan trap, schist, sand stone and lime stone. The details of parent rock formations of individual pedons is given below.

In Ballary, Budagumpa, Timmapura, Shivapura, Devapur and Kushtagi the geological formation is of granitic complex. The granites are pink to grey coloured, coarse, to medium grained.

Sandur upland and midland come under Bellary district. The geology of this area is mainly covered by weakened schist.

The geology of Kulageri is covered by lower Kaladagi series. The Archean rocks to the South-west of Bijapur are overlain by a series of unfossiliferous metamorphosed sedimentary rocks known as Kaladagi series, about 8000 to 10,000 ft. thick, comprises basal conglomerates, arkoses, sandstones quartzites and red stones overlain by siliceous limestones, hornstones, and shales, The cliffs of this area are chiefly formed of pale buffy thick bedded quartzic sand stone, with purple laminae stained red externally in many

places. The geology of Jamakhandi is covered by alluvium of sand stone and quartzite.

### 3.1.3. Climate

The climatic data of the zone is presented in Table 2.

This zone receives low rainfall among the different zones in the state. The total average rainfall received in 30 rainy days ranges from 460 to 630mm. Kudalagi and Hospet taluks are among those that receive total average rainfall ranging from 630 to 637mm whereas Sandur taluk receives 785 mm rainfall. The moisture regime of the region is Typic Aridic type with 60-90 number of days SMCS moisture after summer solstice at temperature  $\geq 8^{\circ}\text{C}$  (Sehgal and Mandal, 1993).

Out of the annual total rainfall 62 per cent (356mm) is received between June to September, 13 per cent (73mm) from April to May an early rainfall and about 22 per cent (127mm) rainfall is received between October and November. In this zone, in 80 per cent of the years, average annual rainfall was less than 435mm and in remaining 20 per cent of the years it was more than 435mm. On an average 67.4, 73.0, 78.9, 136.2, 92.7 and 34.5 mm rainfall was received generally in the months of June, July, August, September, October and November respectively. This type of distribution resembles E-4 model ( $D_3, C_1, D_1, E_3$ ) of rainfall distribution given by National Commission on Agriculture.

Table 2. Mean monthly meteorological data of Northern Dry zone

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1. Rain fall (mm)	1.72	2.26	4.74	26.26	55.20	65.34	77.20	77.60	133.40	101.20	31.40	8.32	584.60
2. Rainy days	0.16	0.18	0.36	2.06	3.72	4.74	6.82	5.76	7.08	5.80	1.84	0.54	39.21
3. Average No. of rainy days with rainfall more than (20mm)	0.2	0.0	0.2	0.0	1.0	1.0	1.0	1.3	1.0	1.0	0.2	0.0	6.06
4. Average No. of rainy days with rainfall more than (50mm)	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.0	0.3	0.0	0.0	1.7
5. Evaporation (mm/day)	5.9	7.9	10.0	10.7	12.5	9.9	6.3	6.8	6.6	5.7	5.6	5.2	-
6. Maximum temp. °C	30.5	33.7	36.6	38.3	38.0	34.2	31.7	31.1	31.5	31.1	30.3	29.6	-
7. Minimum temp. °C	15.5	17.5	20.8	23.9	24.4	23.0	22.4	22.2	22.0	21.1	18.1	15.1	-
8. Relative humidity (%)	44.0	37.0	35.0	38.0	43.0	64.0	71.0	70.0	70.0	60.0	50.0	46.0	-
9. Wind speed km/hr.	4.8	7.6	7.8	9.0	13.9	20.8	20.4	20.4	13.5	7.7	6.7	5.1	-

The mean maximum temperature of the zone is 29.6°C (December-January) to 38.5°C (April-May) and the mean minimum temperature ranges from 15°C (December-January) to 24°C (April-May). Relative humidity ranges from 35 per cent (February, March, April) to 70 per cent (July, August, September).

The climatic data of the study sites is briefed below.

Ballary, Budgumpa and Kushtagi, have got semiarid type of climate. South west monsoon accounts for 82 per cent of total annual rainfall. The average precipitation is 696.6 mm in Ballary and Budgumpa and 644 mm in Kushtagi. Average annual maximum and minimum temperatures are 33.7°C to 22.1°C respectively. The winter season is relatively cool and dry, with December being the coldest month, March April and May are the hottest months. The temperature regime is hypothermic (Anon, 1970).

The average annual rainfall is 696.6 and 574.9 mm in Timmapura and Sandur respectively. The maximum temperature being 33.7°C and the minimum is 22.1°C. September is the rainiest month. April and May are the hottest months and December is the coldest month.

In case of Kulageri and Jamakhandi, the climate is Tropical and arid and is dry throughout the year, except during the south west monsoon. The maximum temperature being 41.5°C.

at Kulageri and minimum 11.1°C in December where as 38.6°C and 17.2°C being the maximum and minimum temperatures at Jamakhandi. The average rainfall of Kulageri cross is 573.9 mm and 548.8 mm in Jamakhandi . September is the rainest month (Anon,1966).

#### 3.1.4 Natural vegetation

The natural vegetation in Northern Dry Zone ranges from tropical thorn forest to tropical dry deciduous type. The important species are both shrubs and trees viz., *Butea superba*, *Zigypous Zizuba*, *Anona squamosa*, *Acacia nilotica*, *Prosopis juliflora*, *Zizypus xylopora*, *Cassia auriculata*, *Mangifer indica*, *Acacia arabica*, *Tamarindus indica*, *Azadirachata indica*, *Mangifer indica*, etc.

### 3.2. Description of soil pedons

#### 3.2.1. Site characters and description of pedons

The terminology used for the description of site and pedons are as per Soil Survey Staff (1951).

##### Pedon -1 (Ballary)

Location	: Near Ballary village (6 kms from Budgumpa cross) on NH-13, near high tension line (Tq. Koppal).
Physiography	: Undulating to rolling upland.
Slope	: 2 per cent
Erosion	: Severe.
Drainage	: Well drained.
Parent rock	: Granite.
Present land use	: Cultivated land (Sesamum)

Horizon	Depth(cm)	Description
Ap	0-12	Reddish yellow ( 5YR 6/6, d) sandy and Yellowish red ( 5YR 4/6, m); weak, fine, subangular blocky; slightly hard (dry), friable (moist), non plastic and slightly sticky(wet).
Bt <sub>1</sub>	12-29	Reddish brown (2.5 YR 5/4, d) sandy loam and dark reddish brown (2.5 YR 3/4, m); moderate, medium, subangular blocky, slightly hard (dry), firable (moist) non plastic and slightly sticky (wet); clay skins on ped surface.
Bt <sub>2</sub>	29-47	Reddish brown ( 2.5YR 5/4 d) sandy clay loam and dark reddish brown (2.5 YR 3.5/4 m), massive, slightly hard (dry) very friable (moist), slightly plastic and slightly sticky (wet) clay skins on ped surface.
BC	47-76	Light red ( 2.5 YR 6/6 d) sandy loam and red (2.5 YR 4/6 m); massive, slightly hard (dry), friable (moist), slightly plastic and slightly sticky (wet).
C <sub>1</sub>	76-105	Reddish yellow ( 5 YR 7/6 d) loamy sand and reddish yellow (5 YR 6/6 m); massive; slightly hard (dry), very

friable (moist), non plastic and slightly sticky (wet)

C<sub>2</sub>                    105+            Weathered granite

Pedon - 2 (Budagumpa cross)

Location                    : 1 Km from Budagumpa cross on Koppal road

Physiography                : Gently undulating mid upland

Slope                        : 1-2 per cent

Erosion                      : moderate.

Drainage                     : Well drained.

Parentrock                 : Granite gneiss

Present landuse             : Cultivated land (Groundnut).

Horizon	Depth(cm)	Description
Ap	0-12	Red (2.5 YR 4/6, d) sandy loam and dark reddish brown (2.5 YR 3/4, m); moderate, fine, subangular blocky; slightly hard (dry), friable (moist) slightly plastic and slightly sticky (wet).
B	12-26	Reddish brown ( 2.5 YR 4/4, d) sandy loam and dark reddish brown (2.5 YR 3/4, m); moderate, medium, subangular blocky; slightly hard (dry) friable (moist), plastic and sticky (wet).
Bt <sub>1</sub>	26-51	Red (2.5 YR 4/6, d) sandy loam and dark reddish brown (2.5 YR 3/5, m);weak, medium, subangular blocky; slightly hard (dry), very friable



LANDSCAPE



BULAGUMPA PEDON

		(moist), plastic and slightly sticky (wet), clay skins on ped surface.
Bt <sub>2</sub>	51-82	Red ( 2.5 YR 5/6, d) sandy clay loam and red (2.5 YR 4/6, m);weak, medium, subangular blocky; slightly hard (dry), very friable (moist), Plastic and sticky (wet), clay skins on ped surface.
Bt <sub>3</sub>	82-104	Reddish brown ( 2.5 YR 5/4 d) sandy loam and reddish brown ( 2.5 YR 4/4, m); weak, medium subangular blocky; slightly hard ( dry), friable (moist,) plastic and sticky (wet).
BC	104-156	Reddish yellow ( 5 YR 7/6, d) sandy loam and reddish yellow (5YR 6/6, m), weak, medium, subangular blocky; slightly hard (dry), fiabile (moist) plastic and slightly sticky (wet).

Additional note: Soils are most productive if supported by irrigation and are most suited for groundnut.

Pedon-3 (Timmapura)

Location	: 9 Kms from Kampli, on Kampli-Bellary road
Physiography	: Undulating to rolling midland.
Slope	: 1-3 per cent
Erosion	: Moderate
Drainage	: Well drained
Parent rock	: Granite gneiss

Present landuse : cultivated land (Groundnut, maize)

Horizon	Depth(cm)	Description.
Ap	0-15	Yellowish red ( 5 YR 4/6, d) sandy, and reddish brown (5YR 4/4, m); moderate, fine, sub angular blocky; slightly hard (dry) very friable (moist), slightly plastic and slightly sticky (wet).
B <sub>1</sub>	15-50	Yellowish red ( 5 YR 4/6, d) loamy sand and reddish brown ( 5YR 4/4, m);moderate, medium, subangular blocky;, slightly hard (dry), friable (moist) , non plastic and slightly sticky (wet)
Bt <sub>1</sub>	50-140	Red (2.5 YR 4/5, d) Sandy loam dark and reddish brown red (2.5 YR 3.5/4, m), moderate medium, subangular blocky;, slightly hard (dry), friable (moist), plastic and slightly sticky (wet), clay skins on ped surface.
Bt <sub>2</sub>	140-180	Red ( 2.5 YR 4/6, d) sandy clay loam and dark red ( 2.5 YR 3.5/6, m), moderate, medium , subangular blocky; hard (dry) friable (moist), plastic and sticky (wet), clay skins on ped surface.

BC                    180-228    Red (2.5 YR 4/6, d) sandy clay loam and dark red ( 2.5 YR 3/6, m);weak, medium, subangular blocky; slightly hard(dry) friable moist) plastic and sticky (wet).

C                    225-300    Weathered parent material.

Pedon - 4 (Sandur upland)

Location                : 2 kms from Sandur towards west.

Physiography            : Undulating upland.

Slope                    : 3 per cent.

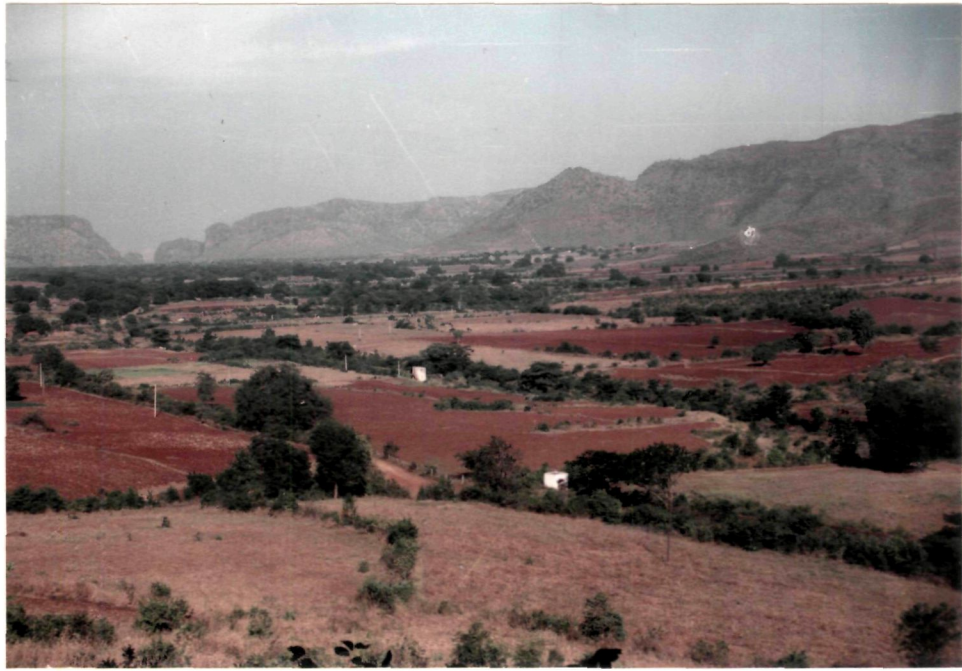
Erosion                 : Severe.

Drainage                : Well drained.

Parent rock             : Schist.

Present land use        : Cultivated land ( Groundnut)

Horizon	Depth(cm)	Description
Ap	0-15	Reddish brown (5 YR 4/3, d) sandy clay loam and dark reddish brown (5 YR 3/3, m);moderate fine, subangular blocky; hard (dry), friable (moist), plastic and sticky (wet).
Bw	15-30	Reddish brown ( 5 YR 5/3, d) sandy clay loam and reddish brown ( 5 YR 4/3, m);moderate, medium, subangular blocky;, slightly hard (dry), friable (moist), plastic and sticky (wet).



LANDSCAPE



SANLUR MIDLAND PEDON

Pedon - 5 (Sandur midland)

Location : 1 Km from Sandur towards Kudalagi near forest nursery.

Physiography : Gently sloping midland

Slope : 1-2 per cent

Erosion : Moderate.

Drainage : Well drained

Parent rock : Weathered schist

Present land use : Cultivated land ( jowar, Maize).

Horizon	Depth(cm)	Description
Ap	0-10	Reddish brown (2.5 YR 4/4,d) sandy clay loam and dark reddish brown (2.5 YR 3/4, m); moderate, medium, subangular blocky; slightly hard (dry), friable (moist), plastic and sticky (wet)
Bw	10-43	Reddish brown (5 YR 5/4, d) sandy clay loam and reddish brown ( 5 YR 4/4, m); moderate, medium , subangular blocky; slightly hard (dry), friable ( moist), plastic and sticky (wet).
C	43-81	Weathered schist.

Pedon - 6 (Shivapur)

Location : 7 Kms from Kudalagi towards Hospet on NH 13.

Physiography : Gently sloping midland

Slope : 2-3 per cent

Erosion : Moderate.  
 Drainage : Well drained  
 Parent rock : granite  
 Present land use : Cultivated land (Sorghum, maize)

Horizon	Depth(cm)	Description
<b>Ap</b>	0-12	Yellowish red ( 5YR 5/6, d) loamy sand and yellowish red ( 5 YR 4/6, m), moderate, fine-medium, subangular blocky; slightly hard (dry), friable (moist), slightly plastic and sticky (wet)
<b>Bt<sub>1</sub></b>	12-30	Yellowish red ( 5 YR 5/6,d) sandy loam and Yellowish red ( 5 YR 4/6,m). Strong, medium, subangular blocky; slightly hard (dry), friable (moist), non plastic and slightly sticky (wet), clay skins on ped surface.
<b>Bt<sub>2</sub></b>	31-70	Reddish yellow (5 YR 6/6, d) sandy loam and Yellowish red (5 YR 5/6, m), massive, slightly hard (dry) vey friable (moist), slightly plastic and slightly sticky (wet) clay skins on ped surface.
<b>C</b>	70-108	Weathered granite.

Pedon-7 (Devapur)

Location : 21 Kms from Hospet on NH-13 towards Timmapura.

Physiography : Gently sloping upland  
 Slope : 2 per cent  
 Erosion : moderate  
 Drainage : Well drained  
 Parent rock : Granite gneiss  
 Present land use: : Cultivated land (Sorghum, Redgram)

Horizon	Depth(cm)	Description
Ap	0-14	Reddish yellow ( 5 YR 6/6, d) sandy, and yellowish red (5 YR 4/6, m), moderate, medium, subangular blocky; slightly hard (dry), firm (moist), non plastic and slightly sticky (wet).
Bt	14-36	Reddish yellow ( 5 YR 7/6, d) loamy sand and yellowish red ( 5YR 5/6, m);weak, medium, subangular blocky; hard (dry), friable (moist), slightly plastic and slightly sticky (wet), clay skins on ped surface.
C	36-72	Weathered schist.

Pedon - 8 (Kulageri cross)

Location : About 400 m towards north of Kulageri cross on way to Bagalkot on left hand side.  
 Physiography; : Gently undulating plain.  
 Slope : About 1-2 per cent.  
 Erosion : Moderate.  
 Drainage : Well drained.

Parent rock : Sandstone

Present land use : Cultivated land (Groundnut, maize, sorghum)

Horizon	Depth(cm)	Description.
Ap	0-25	Red (2.5 YR 4/6, d) loamy sand and red (2.5 YR, 4/6, d) moderate, fine, subangularblocky;; slightly hard (dry), friable (moist), plastic and sticky (Wet).
Bt <sub>1</sub>	25-60	Red ( 2.5 YR 4/6, d) sandy loam and dark red ( 2.5 YR 3.5/4, m), weak, medium, subangular blocky; slightly hard (dry), friable (moist), plastic and sticky (wet) clay skins on ped surface.
Bt <sub>2</sub>	60-95	Red (2.5 YR 4/6, d) sandy clay loam and dark red (2.5 YR 3/4, m); weak, medium, subangular blocky; slightly hard (dry), friable (moist), plastic and sticky (wet), clay skins on ped surface.
Bt <sub>3</sub>	95-160	Red (2.5 YR 4/6, d) sandy loam and reddish brown (2.5 YR 3.5/4, m), weak, medium, subangularblocky; hard (dry), friable (moist), slightly plastic and slightly sticky (wet), clay skins on ped surface.

BC	160-200	Red (2.5 YR 4/6, d) sandy loam and dark red (2.5 YR 3/6, m); weak, medium, subangular blocky; slightly hard (dry), friable (moist), plastic and slightly sticky (wet).
C	200-220	Reddish yellow (5 YR 6/8 d) loamy sand and Yellowish red (5 YR 5/6 m), weak, medium, subangular blocky; firm (moist), nonsticky and non plastic (wet).

Pedon - 9 (Kushtagi)

Location	: 1.5 Kms from Kushtagi on way to Gangawati on left hand side.
Physiography	: Gently undulating plain.
Slope	: 2 per cent
Erosion	: slight
Drainage	: well drained.
Parent rock	: granite gneiss.
Present land use	: cultivated land (Bajra, jowar, Groundnut)

Horizon	Depth(cm)	Description
Ap	0-20	Reddish brown (5 YR 4/4, d) sandy loam and yellowish red (5 YR 4/6, m), Moderate, medium, subangular blocky; slightly hard (dry), friable (moist), slightly plastic and slightly sticky (wet).

Bt <sub>1</sub>	20-35	Reddish brown (2.5 YR 3.5/4, d) sandy clay loam and dark reddish brown (2.5 YR 3/4, m), weak, medium, subangular blocky; slightly hard (dry), firm (moist), slightly plastic and slightly sticky (wet) clay skins of ped surface.
Bt <sub>2</sub>	35-60	Reddish brown (2.5 YR 3.5/4, d) sandy clay loam and dark reddish brown (2.5 YR 3/4, m), weak, medium, subangular blocky; slightly hard, (dry), Friable (moist) slightly plastic and slightly sticky (wet), clay skins on ped surface.
BC <sub>1</sub>	60-90	Red (2.5 YR 5/6, d) sandy clay loam and red (2.5 YR 4/6, m), weak, medium, subangular blocky; slightly hard (dry), firm (moist), slightly plastic and slightly sticky (wet).
BC <sub>2</sub>	90-115	Reddish brown ( 5 YR 6/4, d) sandy clay loam and dark reddish brown (5 YR 3/4, m);weak, medium, subangular blocky;; slightly hard (dry), friable (moist), plastic and slightly sticky (wet)
C	115-140	Weathered parent material.

Pedon -10 (Jamakhandi)

Location : 3 Kms away from Jamakhandi, on way to Kunchanur, on left hand site.

Physiography : Gently sloping valley.

Stage : 2 per cent

Erosion : Moderate

Drainage : modertely well drained

Parent rock : Alluvium of sandstone and quartzite.

Present land use : Cultivted land (Coconut, mango, pomegranate plantation, and groundnut)

Horizon	Depth(cm)	Description.
Ap	0-25	Reddish brown (5 YR 4/3,d) sandy loam and dark reddish brown ( 5 YR 3/3, m);moderate, fine, subangular blocky; soft (dry), friable (moist), plastic and sticky (wet).
Bt <sub>1</sub>	25-50	Reddish brown ( 5 YR 4/4,d) sandy clay loam and dark reddish brown ( 5 YR 3/4,m), weak, medium, subangular blocky; slightly hard (dry), friable moist), slightly plastic and slightly sticky (wet), clay skins on ped surface.
Bt <sub>2</sub>	51-80	Reddish brown ( 5 YR 5/4, d) loamy sand and yellowish red ( 5 YR 4/6, m), weak, medium, subangular blocky; slightly hard (dry), friable (moist)

non plastic and slightly sticky (wet),  
clay skins on ped surface.

BC                      81-125      Reddish brown ( 5 YR 5/3, d) Loamy  
sand and reddish brown ( 5 YR 4/4,  
m); weak, medium, subangular blocky;  
slightly hard (dry), friable (moist)  
slightly plastic and sticky (wet).

### Methods of soil analysis

#### 3.3.1. Preparation of soil samples.

Soil samples were collected horizon wise from each pedon. The samples were dried under shade. These were ground in a wooden pestle and mortar, and then passed through 2 mm sieve. The mineral material left over 2 mm sieve was considered as gravel. These gravels were washed, dried, weighed and expressed as percentage of total soil, 2 mm sieved soil samples were stored in plastic jars for various analytical purposes. A portion of soil sample was drawn from the 2 mm sieve soil and was ground in an agate mortar and then passed through 0.2 mm sieve ( 70 mesh). These samples were stored in buffer paper bags for the analysis of organic carbon, dithionite extractable iron, oxalate extractable iron and surface area of soil.

#### 3.3.2. Morphological properties of soil

Soil colour was measured in both dry and moist conditions using Munsell colour chart. Soil structure and consistence were described as per soil survey staff.

### 3.4. Physical properties

#### 3.4.1. Particle size analysis

Particle size analysis was done by International pipette method as described by Piper (1966), using 1 N, sodium hydroxide as a dispersing agent. From the dispersed suspension, an aliquot of clay plus silt and clay were pipetted at 10 cm depth after a lapse of specified time depending on temperature. The total sand was passed through different sized sieves to quantify very coarse sand (> 1 mm), coarse sand (1.0 to 0.5 mm), medium sand (0.5 to 0.25 mm), fine sand (0.25 to 0.1 mm) and very fine sand (0.1 to 0.05 mm). The fraction that was finer than 0.05 mm was added to silt determined initially by pipetting.

#### Determination of Fine clay

For the determination of fine clay on aliquot containing suspension of clay was centrifuged at a specified period of time (30 min) employing a speed of 2500 rpm with Remi R-24 centrifuge to separate fine clay (< 0.2  $\mu\text{m}$ ). The time required for centrifugation was calculated using a formula (Jackson 1967).

$$t \text{ minutes} = \frac{63.0 \times 10^8 \times \eta \times \log R/S}{(N)^2 \times (r)^2 \times (PD-1)}$$

Where,

R = Radius of rotation of the top of the sediment in the tube (cm)

S = Radius of rotation of the surface of the suspension in the tube (cm)

$N = 2500 \text{ rpm}$

$r = \text{Particle } \overset{\text{diameter}}{\text{radius}} (\mu\text{m})$

$n = 0.00935 \text{ poise}$

$PD = \text{Particle density } (2.65 \text{ mg m}^{-3}).$

After centrifugation 25 ml of suspension was pipetted out into a pre-weighed clean container and kept overnight for oven drying and weighed as fine clay.

#### 3.4.2. Bulk density

Bulk density was determined by core method. A cylindrical metal sampler was pressed into the soil to the desired depth, and was carefully removed to preserve a known volume of sample as it existed *in situ*. The sample was dried to  $105^{\circ}\text{C}$  and oven dry weight was recorded. The bulk density was calculated by knowing the volume of the core and oven dry weight of the sample.

#### 3.4.3. Moisture retention at 33 kPa and 1500 kPa

Moisture retention at 33 kPa and 1500 kPa in the soil samples were determined using pressure plate and pressure membrane apparatus.

#### 3.4.4. Surface area

Soil samples powdered to 80 mesh were dried in an oven at  $105^{\circ}\text{C}$  for 24 hours. One gram sample was treated with 3 ml of EGME (Ethylene Glycol Monoethyl Ether) and kept in a evacuating desiccator over  $\text{CaCl}_2$ , evacuated for 45 minutes using a vacuum pump and the sample was weighed 3-6 hours after

shutting the pump as described by Carter *et al* (1965). Evacuation was repeated until a constant weight was attained. The surface area was computed from the quantity of EGME retained.

### 3.5. Chemical properties

#### 3.5.1. Soil reaction

Soil pH was determined in 1:2.5 soil-water suspension and in 1:2.5 soil: N KCl solution ( Jackson, 1967) by potentiometric method.

#### 3.5.2. Electrical conductivity

Electrical conductivity was determined in 1:2.5 soil-water extract using conductivity bridge (Systronics, 304 digital, direct reading conductivity bridge).

#### 3.5.2. Organic carbon

The organic carbon content was determined using finely ground soil sample, by Walkey and Black's wet oxidation method as described by Jackson (1967).

#### 3.5.4. Exchangeable cations

The exchangeable cations were extracted by neutral normal ammonium acetate as described by Thomas (1982). The exchangeable potassium and sodium were determined by using flame photometer. Exchangeable calcium and magnesium were determined by Versenate titration method.

### 3.5.5. BaCl<sub>2</sub> -TEA Extractable acidity

Ten gram of soil sample was leached with a solution containing 0.5 N BaCl<sub>2</sub> and 0.055 N TEA neutralized with HCl to pH 8.2 . The exchange acidity resulting from the replacement of H<sup>+</sup> and Al<sup>3+</sup> ions and from dissociation of acidic groups was neutralised by weak base, triethanolamine. The left over weak base was determined by titrating with 0.2 N HCl using bromocresol green methyl red mixed indicator , to the end point in the range from green to purple. Simultaneously a blank was run. The extractable acidity was calculated by the difference between blank and sample titrations.

### 3.5.6. Cation Exchange Capacity

Cation exchange capacity of soil was determined by ammonium acetate method ( Black, 1965). A known quantity of sample was saturated with NH<sub>4</sub><sup>+</sup> using neutral normal NH<sub>4</sub>OAC, the excess NH<sub>4</sub>OAC was washed with isopropyl alcohol. The quantity of NH<sub>4</sub><sup>+</sup> retained on the exchange surface was replaced using acidified ( 0.005 N HCl) 10% KCl solution. Ammonium in the extract was estimated by microkjeldahl technique. The CEC thus obtained is designatd as CEC<sub>7</sub> and CEC<sub>sum</sub> (CEC<sub>s</sub>) is the sum of exchangeable cations and BaCl<sub>2</sub>-TEA acidity.

### 3.5.7. Dithionite extractable Iron (Fe<sub>d</sub>)

It was extracted by the dithionite citrate. Bicarbonate method as described by Mehra and Jackson (1960) Fe was colourometrically determined by using Spectrophotometer.

### 3.5.8. Oxalate Extractable Iron ( Fe<sub>o</sub> )

0.25 gm of 100 mesh sieved soil sample was extracted with 10 ml of 0.2 m acid ammonium oxaliate as described by Schwertaman (1973) and Fe was determined using spectrophotometer.

**CHAPTER - IV**

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**EXPERIMENTAL RESULTS**

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## IV EXPERIMENTAL RESULTS

The important morphological features and laboratory analytical data of the soils under study are presented under following headings.

- 1) Morphological features of the soils.
- 2) Physical properties of the soils
- 3) Chemical properties of the soils.

### 4.1. Morphological features of the soils

The site characteristics and detailed description of the pedons are given in Chapter III and important morphological features are presented in Table 3.

**Red** soils developed on different geological formations exhibited a wide variation in solum depth. In Shivapur, Ballary and Jamakhandi pedons solum depth ranged from 70-80 cm. Solum was very deep in Timmapura pedon ( 225 cm) followed by Kulageri pedon where it was 200 cm. Solum depth of Budagumpa and Kushtagi were 104 cm and 115 cm, respectively.

#### 4.1.1. Colour

Bellary pedon exhibited reddish yellow to yellowish red colour at the surface and reddish brown to dark reddish brown at the subsurface. With 5 YR hue at the surface and 2.5 YR hue at the subsurface horizons except in 'C' horizon which again had 5 YR hue.

Table 3. Data on morphological characteristics of the soils

Horizon	Depth (cm)	Colour		Texture	Struc- ture	Consistency
		Dry	Moist			
1	2	3	4	5	6	7
Pedon 1 (Ballary)						
Ap	0-12	5 YR 6/6	5 YR 4/6	gs	1 f sbk	dsh,mfr, wPo,wss
Bt1	12-29	2.5 YR 5/4	2.5 YR 3/4	gsl	2 m sbk	dsh,mfr, wPo,wss
Bt2	29-47	2.5 YR 5/4	2.5 YR 3.5/4	qscl	m	dsh,mvfr,wPs,wss
BC	47-76	2.5 YR 6/6	2.5 YR 4/6	gsl	m	dsh,mfr, wPs,wss
C1	76-105	5 YR 7/6	5 YR 6/6	qls	m	dsh,mvfr,wPo,wss
C2	105+	Weathered granite				
Pedon 2 (Budagumpa cross)						
Ap	0-12	2.5 YR 4/6	2.5 YR 3/4	sl	2 f sbk	dsh,mfr, wPs,wss
B1	12-26	2.5 YR 4/4	2.5 YR 3/4	sl	2 m sbk	dsh,mfr, wP, ws
Bt1	26-51	2.5 YR 4/6	2.5 YR 3/5	qscl	1 m sbk	dsh,mvfr,wP, wss
Bt2	51-82	2.5 YR 5/6	2.5 YR 4/6	qscl	1 m sbk	dsh,mvfr,wP, ws
Bt3	82-104	2.5 YR 5/4	2.5 YR 4/4	gsl	1 m sbk	dsh,mfr, wP, ws
BC	104-156	5 YR 7/6	5 YR 6/6	gsl	1 m sbk	dsh,mfr, wP, wss
Pedon 3 (Timmapura)						
Ap	0-15	5 YR 4/6	5 YR 4/4	gsl	2 f sbk	dsh,mvfr,wPs,wss
B1	15-50	5 YR 4/6	5 YR 4/4	vgsl	2 m sbk	dsh,mfr, wPo,wss
Bt1	50-140	2.5 YR 4/5	2.5 YR 3.5/4	vgqsl	2 m sbk	dsh,mfr, wP, wss
Bt2	140-180	2.5 YR 4/6	2.5 YR 3.5/6	vgqsl	2 m sbk	dh, mfr, wP, ws
BC	180-225	2.5 YR 4/6	2.5 YR 3/6	vgqsl	1 m sbk	dsh,mfr, wP, ws
C	225-300	5 YR 6/6	nd	vgsl	1 m sbk	dsh,mfr, wP, ws
Pedon 4 (Sandur upland)						
Ap	0-15	5 YR 4/3	5 YR 3/3	qscl	2 f sbk	dh, mfr, wP, ws
Bw	15-30	5 YR 5/3	5 YR 4/3	vgqsl	2 m sbk	dsh,mfr, wP, ws
Pedon 5 (Sandur midland)						
Ap	0-10	2.5 YR 4/4	2.5 YR 3/4	scl	2 f sbk	dsh,mfr, wP, ws
Bw	10-43	5 YR 5/6	5 YR 4/4	scl	2 m sbk	dsh,mfr, wP, ws
C	43-81	Weathered schist				
Pedon 6 (Shivapur)						
Ap	0-12	5 YR 5/6	5 YR 4/6	ls	2 f sbk	dsh,mfr, wPs,ws
Bt1	12-30	5 YR 5/6	5 YR 4/6	sl	2 m sbk	dsh,mfr, wPo,wss
Bt2	30-70	5 YR 6/6	5 YR 4/6	sl	m	dsh,mfr, wPs,wss
C	70-108	Weathered schist				

1	2	3	4	5	6	7
Pedon 7 (Devapur)						
Ap	0-14	5 YR 6/6	5 YR 4/6	gs	2 m sbk	dsh,mfi,wPo,wss
Bt	14-36	5 YR 7/6	5 YR 4/6	gs1	1 m sbk	dh, mfr,wPs,wss
C	36-72	Weathered schist				
Pedon 8 (Kulageri cross)						
Ap	0-25	2.5 YR 4/6	2.5 YR 4/6	gs1	2 m sbk	dsh,mfr,wP, ws
Bt1	25-60	2.5 YR 4/6	2.5 YR 3.5/4	gs1	1 m sbk	dsh,mfr,wP, ws
Bt2	60-95	2.5 YR 4/6	2.5 YR 3/4	vg scl	1 m sbk	dsh,mfr,wP, ws
Bt3	95-160	2.5 YR 4/6	2.5 YR 3.5/4	vg scl	1 m sbk	dh, mfr,wSp,wss
BC	160-200	2.5 YR 4/6	2.5 YR 3/6	vg scl	1 m sbk	dsh,mfr,wP, wss
C	200-220	Weathered sandstone				
Pedon 9 (Kushtagi)						
Ap	0-20	5 YR 4/4	5 YR 3/4	sl	2 m sbk	dsh,mfr,wPs,wss
Bt1	20-35	2.5 YR 3.5/42.5	YR 3/4	vg scl	1 m sbk	dsh,mfi,wPs,wss
Bt2	35-60	2.5 YR 3.5/42.5	YR 3/6	vg scl	1 m sbk	ds, mfr,wPs,wss
BC1	60-90	2.5 YR 4/4	2.5 YR 3/4	vg scl	1 m sbk	dsh,mfi,wPs,wss
BC2	90-115	2.5 YR 6/4	2.5 YR 5/4	vg scl	1 m sbk	dsh,mfr,wP, wss
C	115-140	Weathered granite gneiss				
Pedon 10 (Jamakhandi)						
Ap	0-25	5 YR 4/3	5 YR 3/3	scl	2 f sbk	ds, mfr,wP, ws
Bt1	25-50	5 YR 4/4	5 YR 3/4	scl	1 m sbk	dsh,mfr,wPs,wss
Bt2	50-80	5 YR 5/4	5 YR 4/6	gscl	1 m sbk	dsh,mfr,wPo,wss
C	80-125	5 YR 5/3	5 YR 4/6	scl	1 m sbk	dsh,mfr,wPs,ws

The colour of Budagumpa soil was red to dark reddish brown. The hue remained redder ( 2.5 YR) throughout the solum and became yellower ( 5YR) in C horizon.

In Timmapura pedon the colour changed from yellowish red to reddish brown both in the surface and subsurface horizons. The hue was yellower ( 5YR ) in the first two horizons and redder ( 5 YR ) in the remaining solum.

The colour of Sandur upland soil was almost reddish brown with 5 YR hue throughout the pedon. However, Sandur midland soil showed redder hue ( 2.5 YR ) at the surface and yellower hue ( 5YR ) in the subsurface.

In Shivapur pedon the colour ranged from yellowish red at the surface and reddish yellow in the third horizon, The hue remained yellower (5 YR) throughout the solum.

Devapur pedon exhibited red colour at the surface and red to dark red colour at the subsurface. The hue remained redder ( 2.5 YR ) throughout the solum and became yellower (5YR) in 'C' horizon.

Kulageri pedon exhibited red colour at the surface and red to dark red colour in the subsurface. The hue remained redder ( 2.5 YR ) throughout the solum and became yellower ( 5 YR ) in 'C' horizon.

In case of Kushtagi pedon the colour ranged from reddish brown to yellowish red with 5 YR hue at the surface.

In subsurface the colour ranged from reddish brown to dark reddish brown with redder hue ( 2.5 YR), , where as in Jamakhandi pedon the colour ranged from reddish brown to dark reddish brown in surface and subsurface horizons with 5 YR hue throughout the pedon.

#### 4.1.2. Structure

Structure of Ballary pedon ranged from weak, fine, subangular blocky to massive. Budagumpa and Timmapura pedons exhibited moderate, fine, subangular blocky to weak medium subangular blocky structure.

In case of Sandur upland and midland pedons structure varied from moderate fine, subangular blocky to moderate, medium subangular blocky. The structure of Shivapur pedon ranged from moderate, fine-medium, subangular blocky to massive where as in Devapur and Kushtagi pedons the structure varied from moderate, medium, sub angular blocky to weak, medium, subangular blocky.

In case of Kulageri and Jamakhandi pedons structure varied from moderate, fine, subangular blocky to weak , medium, subangular blocky.

The structure development was good in surface horizons compared to subsurface horizons.

#### 4.1.3. Consistence, stickiness and plasticity

The consistency of the pedons ranged from friable to very friable when moist and slightly hard to hard when dry.

They were slightly sticky to sticky and non plastic to plastic when wet. Cementation was weak in all the pedons. Clay skins were exhibited on ped faces in majority of the pedons except Sandur upland and midland.

#### 4.1.4. Horizon sequence

Ballary pedon exhibited Ap-Bt-BC-C horizon sequence. Ap-B-Bt-BC sequence was observed in case of Budagumpa pedon. Kulageri and Kushtagi pedon exhibited Ap-Bt-BC-C horizon sequence, Shivapur, Devapur and Jamakhandi showed Ap-Bt-C horizon sequence where as Ap-Bw-C horizon sequence was observed in Sandur pedons. Horizon sequence in Timmapura, pedon was Ap-B-Bt-BC-C.

#### 4.2. Physical properties

##### 4.2.1. Particle size composition and distribution

The data pertaining to particle size composition and distribution of soils is given in Table 4.

##### 4.2.1.1. Gravel content and distribution

The coarse fragments left over 2 mm sieve after the preparation of soil samples for further laboratory analysis are designated as gravels. The content of gravels varied from 22 per cent in Ap horizon to 38 per cent in C horizon, gravel content was minimum in Ap horizon of Ballary pedon.

In Budgumpa pedon, the gravel content varied from 2 to 29 per cent. Gravel content was maximum in BC horizon and minimum in Bt horizon. The gravel content of Timmapura pedon

Table 4. Data on particle size distribution in soils (Expressed on per cent oven dry basis)

Horizon	Depth (cm)	Gravels (>2.0 mm)	Very coarse sand	Coarse sand	Medium sand	Fine sand	Very fine sand	Total sand (0.05- 2.0mm)	Silt (0.002- 0.05mm)	Clay (<0.002 mm)	Very fine clay (0.2mm)	Texture class
1	2	3	4	5	6	7	8	9	10	11	12	13
Pedon 1 (Ballary)												
Ap	0-12	22.0	25.8	19.5	16.2	17.7	8.3	87.5	4.5	8.0	2.2	s
Bt1	12-29	29.0	15.4	10.7	11.4	15.0	8.6	61.1	18.1	20.8	8.4	sl
Bt2	29-47	29.0	23.8	16.9	6.7	6.2	5.5	59.1	16.3	24.6	9.3	scl
BC	47-76	36.0	20.2	14.2	11.4	12.3	5.3	63.4	18.4	18.2	5.6	sl
C1	76-105	38.0	19.6	21.3	18.8	14.2	7.2	81.1	4.5	14.2	4.0	ls
C2	105+	nd	17.8	23.7	16.8	14.2	10.9	83.4	4.2	12.4	3.2	ls
Pedon 2 (Budagumpa)												
Ap	0-12	6.0	20.5	13.6	13.5	13.6	9.7	73.9	12.0	14.1	6.2	sl
B1	12-26	2.0	26.9	9.7	9.3	9.9	15.8	71.6	11.2	17.2	7.2	sl
Bt1	26-51	29.0	21.0	10.6	11.2	11.5	15.9	70.2	9.7	20.6	8.6	scl
Bt2	51-82	23.0	25.7	12.6	10.1	9.5	9.1	67.0	6.4	26.6	13.4	scl
Bt3	82-104	17.0	33.5	11.3	9.1	9.0	6.5	69.4	10.2	20.4	10.3	sl
BC	104-156	22.0	36.7	14.0	8.32	9.2	5.5	73.7	10.1	16.2	7.1	sl
Pedon 3 (Timmapura)												
Ap	0-15	36.0	18.5	15.0	16.3	21.8	6.4	77.5	10.2	12.3	2.2	sl
B1	15-50	56.0	14.8	16.3	15.8	22.4	8.1	71.4	12.4	16.2	3.4	sl
Bt1	50-140	63.0	16.9	10.7	10.7	11.6	15.5	64.8	14.1	21.1	6.3	scl
Bt2	140-180	73.0	15.3	7.55	7.52	8.87	7.9	47.0	22.8	30.2	10.4	scl
BC	180-225	67.0	32.5	7.95	7.02	7.87	6.0	61.2	14.2	24.6	8.5	scl
C	225-300	52.0	11.9	15.7	15.5	15.3	10.7	69.1	14.1	16.8	5.3	sl
Pedon 4 (Sandur upland)												
Ap	0-15	37.0	12.2	7.15	8.02	17.2	13.1	57.6	14.0	28.4	8.2	scl
Bw	15-30	73.0	12.2	9.25	10.6	12.9	10.6	55.5	14.0	30.5	10.4	scl
Pedon 5 (Sandur midland)												
Ap	0-10	8.0	9.5	5.2	7.6	18.4	18.6	59.3	14.1	26.6	12.4	scl
Bw	10-43	2.0	4.8	6.2	8.2	19.1	17.2	55.5	14.0	30.5	15.3	scl
C	43-81	6.0	12.9	11.7	22.3	20.5	7.6	75.0	2.4	22.6	10.2	scl
Pedon 6 (Shivapur)												
Ap	0-12	1.0	19.0	23.4	14.2	14.7	10.0	81.3	8.5	10.2	4.2	ls
Bt1	12-30	1.0	9.5	13.1	23.8	22.9	10.4	79.7	6.0	14.3	7.4	sl
Bt2	30-70	2.0	17.3	16.3	15.9	14.7	11.2	75.4	6.2	18.4	10.5	sl
C	70-108	nd	18.3	19.1	19.1	14.0	7.2	77.6	8.2	14.2	6.7	sl

1	2	3	4	5	6	7	8	9	10	11	12	13
Pedon 7 (Devapur)												
Ap	0-14	22.0	23.9	11.3	19.9	25.0	10.5	90.6	2.2	7.2	2.2	s
Bt	14-36	38.0	14.9	15.6	15.2	17.7	14.9	78.3	9.2	12.5	3.5	sl
C	36-72	23.0	21.1	21.5	18.3	16.5	8.4	85.6	4.6	9.8	2.6	s
Pedon 8 (Kulageri)												
Ap	0-25	40.0	16.7	8.8	9.5	16.4	15.7	67.1	12.3	11.6	3.2	sl
Bt1	25-60	50.0	16.1	9.8	10.5	16.9	15.7	69.0	13.0	18.0	5.4	sl
Bt2	60-95	62.0	23.8	10.0	9.4	13.0	13.3	69.5	10.5	20.0	7.2	scl
Bt3	95-160	60.0	16.7	8.4	6.0	10.2	16.3	57.6	16.4	26.0	9.5	scl
BC	160-200	62.0	14.2	8.8	9.3	13.0	12.9	58.2	16.8	25.0	8.2	scl
C	200-220	72.0	16.2	10.9	12.3	16.0	14.9	70.2	14.2	15.0	2.6	sl
Pedon 9 (Kushtaqi)												
Ap	0-20	19.0	11.4	10.7	19.9	17.7	7.3	67.2	14.0	18.8	6.2	sl
Bt1	20-35	66.0	29.4	7.4	8.8	6.9	4.5	57.0	18.2	24.8	8.4	scl
Bt2	35-60	80.0	23.6	4.6	9.2	8.6	3.2	49.2	18.6	32.2	10.1	scl
BC1	60-90	72.0	24.2	7.05	7.72	7.27	5.0	51.1	20.3	28.6	8.3	scl
BC2	90-115	59.0	22.1	8.8	10.3	9.6	6.2	57.0	20.4	22.6	7.3	scl
C	115-140	6.0	26.5	30.5	17.9	8.7	3.3	86.9	2.3	10.8	5.4	ls
Pedon 10 (Jamakhandi)												
Ap	0-25	1.0	12.5	15.0	20.4	12.4	10.2	70.5	6.4	23.1	4.3	scl
Bt1	25-50	2.0	19.2	12.7	17.3	11.2	5.0	65.4	7.2	27.4	8.6	scl
Bt2	50-80	33.0	18.2	12.5	16.0	7.0	5.9	59.6	10.2	30.2	10.4	scl
C	80-125	17.0	10.8	15.2	17.5	15.6	9.9	69.0	8.6	22.4	5.4	scl

ranged from 36 per cent in surface horizon to 73 per cent at 180 cm depth.

The gravel content in Sandur midland pedon ranged from 37 per cent in surface horizon to 73 per cent in subsurface horizon. In midland the gravel content was less and it varied from 2 to 8 per cent.

In Shivapur pedon gravel content was minimum among all the pedons studied and it ranged from 1 to 2 per cent. The gravel content ranged from 22 to 38 per cent in Devapur pedon, where as in Kulageri pedon it ranged from 40-72 per cent, gravel content increased with depth in this pedon.

A wide range was observed in the gravel content of Kushtagi pedon where it varied from 6 to 80 per cent. Gravel content was more in B horizons and very sharply decreased in C horizon.

In Jamakhandi pedon gravel content varied from 1 to 33 percent . A sharp increase in gravel content was observed in 'Bt<sub>2</sub>' horizon. Gravel content was minimum in the surface horizon.

#### 4.2.1.2. Total sand content and distribution

In Ballary pedon, the total sand content ranged from 59.1 to 87.51 per cent. Very soarse sand and coarse sand together comprised bulk of the total sand content. The sand content was more in Ap and C horizons compared to Bt horizons.

The total sand content of Budagumpa pedon ranged from 67.0 to 73.9 per cent. Here also very coarse sand and coarse sand contents together contributed to bulk of the total sand. Total sand content was highest in the surface horizon and was minimum in Bt<sub>2</sub> horizon.

In Tiammapura pedon, total sand content varied from 47.0 to 77.5 per cent. Very coarse sand and fine sand contents contributed to the bulk of the total sand. Very coarse sand decreased with depth. Sand content was minimum in Bt horizons than underlying or overlying horizons.

The total sand content of Sandur upland pedon ranged from 55.5 to 57.6 per cent. The fine sand and very fine sand fractions together comprised bulk of the total sand content and these two fractions decreased with depth where as other sand fractions increased slightly with depth, except very coarse sand, which was uniformly distributed with depth.

In Sandur midland the total sand content varied from 55.5 to 75.0 per cent. Sand content was minimum in 'Bw' horizon compared to Ap and C horizons. Fine sand and very fine sand contents were maximum compared to other sand fractions. Total sand content in Shivapur and Devapur pedons ranged from 75.4 to 81.3 per cent and 78.3 to 90.6 per cent respectively. The content of very fine sand fraction was minimum in both the pedons.

In Kulageri pedon total sand content ranged from 57.6 to 70.2 per cent. Very coarse sand, fine sand and very fine

sand fractions contributed bulk of the total sand. Sand content was minimum in  $Bt_3$  horizons. A fairly uniform distribution of total sand content was observed in this pedon.

In Kushtagi pedon the total sand content ranged from 49.2 to 86.9 per cent. Bulk of the total sand was contributed by very coarse sand.

The total sand content of Jamakhandi pedon ranged from 59.6 to per cent. Very coarse sand, coarse sand and medium sand fractions formed the bulk of the total sand. Sand content was minimum in  $Bt_2$  horizon than other horizons.

In all the pedons studied, Bt or 'Bw' horizons contained less amount of sand compared to underlying and overlying horizons. In majority of the pedons total sand content of surface horizons was maximum.

#### 4.2.1.3. Silt content and distribution

In Ballary pedon the silt content varied from 4.2 to 18.4 per cent it increased upto BC horizon and sharply decreased in C horizon. The silt content of Budagumpa varied from 6.4 to 12.0 per cent. A fairly uniform distribution of silt was observed in this pedon except in  $Bt_2$  horizon. In Timmapura pedon silt content increased with depth in the upper 180 cm and then decreased, it ranged from 10.2 to 22.8 per cent.

In Sandur upland silt was uniformly distributed throughout the pedon and its content was 14 per cent, whereas

in midland silt content ranged from 2.4 to 14.1 per cent. A uniform distribution of silt was seen in upper horizons and it sharply decreased in C horizon.

In Shivapur and Devapur pedons silt content varied from 6.0 to 8.5 per cent and 2.2 to 9.2 per cent, respectively. Silt content of Kulageri pedon ranged from 10.5 to 16.8 per cent. Silt content was highest in BC horizon and lowest in  $Bt_2$  horizon.

In Kushtagi pedon silt content ranged from 2.3 to 20.4 per cent. Silt content increased with depth upto BC horizon and its decrease was very sharp in C horizon.

Silt content of Jamakhandi pedon varied from 6.4 to 10.2 per cent, silt content was minimum in  $Bt_2$  horizon.

#### 4.2.1.4. Clay and fine clay content and distribution

In Ballary pedon, the clay content ranged from 8.0 to 24.6 per cent and fine clay from 2.2 to 9.3 per cent, both the fractions were highest in  $Bt_1$  and  $Bt_2$  horizons compared to other horizons.

The clay content of Budagumpa pedon ranged from 14.2 to 26.6 per cent and fine clay from 6.2 to 13.4 per cent. Clay and fine clay contents increased upto  $Bt_2$  horizon and then decreased. In Timmapura, clay and fine clay content ranged from 12.3 to 30.2 per cent and 2.2 to 10.4 per cent respectively. In Sandur upland pedon clay content ranged from 28.4 to 30.5 per cent and fine clay from 8.2 to 10.4 per cent.

In midland corresponding values were 22.6 to 30.5 per cent and 10.2 to 15.3 per cent, respectively. The fine clay content was highest in this pedon among all the pedons studied. The clay content of Shivapur and Devapur pedons ranged from 10.2 to 18.4 per cent and 7.2 to 12.5 per cent, respectively and fine clay from 4.2 to 10.5 per cent and 2.2 to 3.5 per cent, respectively.

In Kulageri pedon clay content varied from 11.6 to 26.0 per cent and fine clay from 3.2 to 9.5 per cent. The clay content of Kushtagi pedon was the highest among all the pedons studied and ranged from 10.8 to 32.2 per cent and fine clay content varied from 5.4 to 10.1 per cent. In case of Jamakhandi pedon clay and fine clay contents varied from 22.4 to 30.2 per cent and from 4.3 to 10.4 per cent, respectively.

In all the pedons studied clay content increased with depth upto Bt horizon and then decreased.

#### 4.2.1.5. Texture class

Ballary pedon exhibited sandy texture in the surface horizon and it changed to sandy loam in Bt<sub>1</sub> horizon and sandy clay loam in Bt<sub>2</sub> horizon and C horizon exhibited loamy sand texture. In Budagumpa pedon texture remained sandy loam in Ap and B<sub>1</sub> horizons and changed to sandy clay loam in Bt<sub>1</sub> and Bt<sub>2</sub> horizons and became sandy loam in Bt<sub>3</sub> and BC horizons.

In Timmapura pedon texture was sandy loam in surface horizons. It changed to sandy clay loam in rest of the profile except in C horizon.

In Sandur upland and midland texture was sandy clay loam and it remained same throughout the pedons.

Texture of Shivapur pedon changed from loamy sand in surface horizon to sandy loam in subsequent horizons. Where as in Devapur pedon texture varied from sandy in the surface to sandy loam in subsurface horizon.

Texture of Kulageri pedon was sandy loam in A and C horizons, sandy clay loam in Bt and BC horizons.

In Kushtagi pedon texture was sandy loam in the surface horizon and changed to sandy clay loam in subsurface horizons and was loamy sand in C horizon. Texture of surface horizon of Jamakhandi was uniformly sandy clay loam throughout the pedon.

#### 4.2.2. Bulk density

The data on bulk density is presented in Table 5. Bulk density of Ballary pedon ranged from 1.42 to 1.77 Mg m<sup>-3</sup>. Bulk density was lowest in the surface and was highest in C horizon. In Budagumpa cross pedon lowest bulk density value of 1.34 Mg m<sup>-3</sup> was observed in the surface horizon and it increased to 1.57 Mg m<sup>-3</sup> in Bt horizon.

Surface horizon of Timmapura pedon had a bulk density value of 1.45 Mg m<sup>-3</sup>. In Sandur upland surface horizon bulk density was 1.42 Mg m<sup>-3</sup> and in midland it ranged from 1.43 Mg m<sup>-3</sup> in surface horizon to 1.70 Mg m<sup>-3</sup> in C horizon. The

Table 5. Data on bulk density, specific surface area and moisture retention characteristics of soils

Horizon	Depth (cm)	Bulk density ( $\text{mg m}^{-3}$ )	Surface area ( $\text{m}^2 \text{gm}^{-1}$ )	Moisture retention	
				33 kPa	1500 kPa (%)
1	2	3	4	5	6
Pedon 1 (Ballary)					
Ab	0-12	1.42	82.00	5.26	2.16
Bt1	12-29	1.56	68.20	12.82	5.90
Bt2	29-47	1.47	71.60	15.02	2.10
<b>BC</b>	47-76	1.62	63.90	11.92	4.00
<b>C1</b>	76-105	1.77	51.60	9.10	3.80
C2	105+	nd	44.00	8.60	3.62
Pedon 2 (Budagumpa)					
Ap	0-12	1.34	45.90	9.10	4.21
B1	12-26	1.37	52.60	10.06	4.86
Bt1	26-51	1.41	65.70	12.10	5.98
Bt2	51-82	1.35	82.40	16.00	8.92
Bt3	82-104	1.42	69.30	13.00	7.10
<b>BC</b>	104-156	1.57	55.60	10.92	5.00
Pedon 3 (Timmapura)					
Ap	0-15	1.45	48.00	4.98	3.00
B1	15-50	nd	52.40	6.10	3.90
Bt1	50-140	nd	68.20	12.00	6.90
Bt2	140-180	nd	92.60	18.13	10.46
<b>BC</b>	180-225	nd	81.40	15.00	7.40
C	225-300	nd	71.80	9.10	5.80
Pedon 4 (Sandur upland)					
Ap	0-15	1.42	103.30	19.56	6.80
Bw	15-30	nd	112.30	20.84	7.40
Pedon 5 (Sandur midland)					
Ap	0-10	1.43	98.20	19.32	8.00
<b>Bw</b>	10-43	1.37	114.20	21.00	10.10
C	43-81	1.70	82.40	16.42	7.20
Pedon 6 (Shivapur)					
Ap	0-12	1.42	45.60	8.06	2.78
<b>Bt1</b>	12-30	1.42	53.70	10.14	3.58
Bt2	30-70	1.50	70.20	11.72	4.20
C	70-108		50.60	10.94	3.86

1	2	3	4	5	6
Pedon 7 (Devapur)					
<b>Ap</b>	0-14	1.43	38.10	5.27	2.18
<b>Bt</b>	14-36	nd	44.60	9.39	3.21
<b>C</b>	36-72	nd	40.40	5.72	2.29
Pedon 8 (Kulageri)					
<b>Ap</b>	0-25	1.57	66.40	9.32	3.72
<b>Bt1</b>	25-60	1.64	71.20	14.46	7.10
<b>Bt2</b>	60-95	nd	90.90	16.72	9.10
<b>Bt3</b>	95-160	nd	80.40	17.81	9.90
<b>BC</b>	160-200	nd	70.20	16.91	7.60
<b>C</b>	200-220	nd	50.50	15.01	3.96
Pedon 9 (Kushtagi)					
<b>Ap</b>	0-20	1.51	74.00	12.20	4.90
<b>Bt1</b>	20-35	1.62	89.20	17.30	9.11
<b>Bt2</b>	35-60	nd	98.60	20.60	12.47
<b>BC1</b>	60-90	nd	92.20	18.90	9.24
<b>BC2</b>	90-115	nd	70.10	17.40	7.42
<b>C</b>	115-140	nd	52.40	11.70	4.00
Pedon 10 (Jamakhandi)					
<b>Ap</b>	0-25	1.35	75.60	15.23	6.63
<b>Bt1</b>	25-50	1.47	52.40	19.96	7.18
<b>Bt2</b>	50-80	nd	61.00	12.25	6.34
<b>C</b>	80-125	nd	48.30	8.22	4.26

nd - not determined

surface horizon of Devapur pedon had a bulk density value of  $1.43 \text{ Mg m}^{-3}$ . In case of Shivapur pedon bulk density varied from  $1.42 \text{ Mg m}^{-3}$  to  $1.50 \text{ Mg m}^{-3}$ . Bulk density values of Ap and Bt horizons of Kulageri cross pedon were  $1.57$  and  $1.64 \text{ Mg m}^{-3}$  respectively. In Ap and B1 horizon of Kushtagi pedon, bulk density ranged from  $1.51$  to  $1.62 \text{ mg m}^{-3}$  where as the values were  $1.35$  and  $1.41 \text{ Mg m}^{-3}$  in Jamakhandi pedon.

#### 4.2.3 Surface area

The data pertaining to surface area is presented in Table 5. The surface area of Ballary pedon ranged from  $44.0$  to  $72.6 \text{ m}^2 \text{ g}^{-1}$ . In Budagumpa and Timmapura pedons surface area ranged from  $45.0$  to  $82.4 \text{ m}^2 \text{ g}^{-1}$  and  $48$  to  $98.6 \text{ m}^2 \text{ g}^{-1}$  respectively. In Sandur upland pedon the surface area varied from  $103.3$  to  $112.3 \text{ m}^2 \text{ g}^{-1}$  and in midland from  $82.4$  to  $114.2 \text{ m}^2 \text{ g}^{-1}$ . The surface area of Shivapur and Devapur pedons ranged from  $45.6$  to  $70.2 \text{ m}^2 \text{ g}^{-1}$  and  $38.1$  to  $44.6 \text{ m}^2 \text{ g}^{-1}$  respectively. The surface area in Kulageri pedon varied from  $50.5$  to  $90.9 \text{ m}^2 \text{ g}^{-1}$  where as in Kushtagi pedon the range was from  $52.4$  to  $98.6 \text{ m}^2 \text{ g}^{-1}$ . In Jamakhandi pedon, the surface area ranged from  $48.3$  to  $82.4 \text{ m}^2 \text{ g}^{-1}$ . In all the pedons, the surface area was more in Bt or Bw horizon compared to underlying or overlying horizons. It closely followed the trend of clay distribution.

#### 4.2.4 Moisture retention at 33 kPa and 1500 kPa

The data pertaining to moisture retention at  $33$  and  $1500 \text{ kPa}$  is presented in Table 5.

In Ballary pedon moisture at 33 kPa ranged from 5.26 to 15.02 per cent and 2.16 to 7.10 per cent at 1500 kPa. Available water holding capacity increased upto 47 cm and then decreased.

33 kPa water content ranged from 9.10 to 16.00 per cent and 4.21 to 8.92 per cent at 1500 kPa in Budagumpa pedon. Available water content increased upto  $Bt_2$  horizon and decreased.

In Timmapura pedon moisture content at 33 kPa ranged from 4.98 to 18.13 per cent and at 1500 kPa from 3.0 to 10.46 per cent.

Moisture content at 33 kPa ranged from 4.98 to 18.13 per cent and from 3.00 to 10.46 per cent at 1500 kPa in Sandur upland pedon. In midland pedon the moisture content at 33 kPa and 1500 kPa varied from 16.42 to 19.32 per cent and 7.20 to 10.10 per cent respectively.

The available water capacity was relatively uniform in Shivapur pedon where moisture content at 33 kPa ranged from 8.06 to 11.72 per cent and 2.78 to 4.20 per cent at 1500 kPa.

33 kPa water content ranged from 5.27 to 9.39 per cent and 2.18 to 3.21 per cent at 1500 kPa in Devapur pedon.

In Kulageri pedon moisture at 33 kPa ranged from 9.32 to 17.81 per cent and from 3.72 to 9.90 per cent at 1500 kPa. Available water capacity was relatively uniform in different horizons except in the surface horizon.

In Kushtagi pedon moisture content at 33 kPa ranged from 11.70 to 20.60 per cent and 4.00 to 12.47 per cent at 1500 kPa. Available moisture increased upto Bt<sub>2</sub> horizon and decreased.

In Jamakhandi pedon, Moisture content ranged from 8.22 to 19.96 per cent and 4.26 to 7.18 per cent at 33 kPa and 1500 kPa respectively. Available water content was maximum in B1 horizon and sharply decreased in C horizon.

#### 4.3 Chemical properties

##### 4.3.1 Soil reaction (pH)

Soil reaction was measured both in 1:2.5 soil water suspension and 1:2.5: 1 N KCl solution. The data pertaining to soil pH is presented in Table 6. The data on soil pH measured in 1:2.5 soil water suspension revealed that the soils exhibit a wide range in pH. In Ballary pedon pH increased with depth except in Bt<sub>1</sub> horizon, which recorded the lowest pH value of 5.8. However, the range was from 5.8 to 6.53.

pH ranged from 6.92 to 7.64 in Budagumpa pedon with a decreasing trend in pH from surface horizon to the subsurface horizons. In Timmapura pH varied from 6.74 to 7.21 with a increase in pH in third horizon.

Surface horizon of Sandur upland pedon gave a pH value of 7.90 whereas it was 8.06 in the subsurface horizon. In midland pedon pH ranged from 6.95 to 7.03. In case of Shivapur pedon pH varied from 6.30 to 7.94 showing a increasing

Table 6. pH, EC, organic carbon and dithionite and oxalate extractable Fe in the soils

Horizon	Depth (cm)	pH <sub>0</sub> (1:2.5 soil water)	pH (1:2.5 N KCl)	EC (dS/m)	Organic carbon (%)	Dithio- nite Fe (%)	Oxalate Fe (%)	Fe <sub>0</sub> / Fe <sub>d</sub>
1	2	3	4	5	6	7	8	9
Pedon 1 (Ballary)								
Ap	0-12	6.30	5.63	0.10	0.18	0.75	0.45	0.60
Bt1	12-29	5.80	4.50	0.08	0.15	1.38	0.62	0.45
Bt2	29-47	6.15	4.66	0.05	0.12	1.08	0.57	0.53
BC	47-76	6.28	5.00	0.08	0.06	0.72	0.43	0.60
C1	76-105	6.29	5.01	0.08	0.03	0.51	0.25	0.49
C2	105+	6.53	5.15	0.07	-	0.60	0.31	0.52
Pedon 2 (Budagumpa)								
Ap	0-12	7.64	6.43	0.15	0.30	1.38	0.72	0.52
B1	12-26	7.42	6.12	0.08	0.27	1.35	0.66	0.49
Bt1	26-51	7.41	6.01	0.09	0.21	1.71	0.65	0.38
Bt2	51-82	7.10	5.86	0.10	0.12	1.74	1.08	0.62
Bt3	82-104	7.30	5.74	0.14	0.03	1.11	0.34	0.31
BC	104-156	6.92	5.48	0.08	-	0.93	0.31	0.33
Pedon 3 (Timmapura)								
Ap	0-15	6.84	6.09	0.09	0.36	1.02	0.49	0.48
B1	15-50	6.94	5.70	0.07	0.24	1.44	0.81	0.56
Bt1	50-140	7.21	5.93	0.15	0.15	2.64	1.41	0.53
Bt2	140-180	6.85	5.32	0.05	0.12	2.25	0.91	0.40
BC	180-225	6.74	5.16	0.05	0.12	1.68	0.50	0.30
C	225-300	6.88	5.30	0.06	0.06	0.69	0.21	0.30
Pedon 4 (Sandur upland)								
Ap	0-15	7.90	6.78	0.18	0.69	2.19	1.69	0.77
Bw	15-30	8.06	6.73	0.18	0.60	4.08	2.25	0.55
Pedon 5 (Sandur midland)								
Ap	0-10	6.95	5.32	0.07	0.63	3.69	1.86	0.50
Bw	10-43	7.03	4.63	0.10	0.45	4.28	2.36	0.55
C	43-81	6.98	5.69	0.09	0.39	1.68	0.73	0.43
Pedon 6 (Shivapur)								
Ap	0-12	6.30	5.12	0.06	0.30	1.08	0.42	0.39
Bt1	12-30	6.41	5.03	0.05	0.27	1.41	0.47	0.33
Bt2	30-70	6.80	6.36	0.06	0.15	1.05	0.41	0.39
C	70-108	7.94	6.78	0.17	0.06	0.54	0.22	0.41

1	2	3	4	5	6	7	8	9
Pedon 7 (Devapur)								
Ap	0-14	6.27	5.20	0.07	0.45	0.78	0.28	0.36
Bt	14-36	6.88	5.97	0.43	0.30	1.08	0.51	0.47
C	36-72	7.50	5.91	0.09	0.12	0.38	0.17	0.45
Pedon 8 (Kulageri)								
Ap	0-25	7.29	6.00	0.16	0.45	1.15	0.80	0.69
Bt1	25-60	7.32	6.30	0.20	0.42	1.48	0.85	0.57
Bt2	60-95	7.16	5.86	0.14	0.27	1.41	0.57	0.40
Bt3	95-160	7.47	6.91	0.15	0.12	1.24	0.44	0.35
BC	160-200	8.03	6.90	0.14	0.09	0.86	0.38	0.44
C	200-220	8.25	7.42	0.21	0.06	0.39	0.18	0.46
Pedon 9 (Kushtagi)								
Ap	0-20	6.80	5.59	0.16	0.48	0.64	0.29	0.45
Bt1	20-35	6.56	5.16	0.09	0.45	1.33	0.44	0.33
Bt2	35-60	6.73	5.13	0.10	0.42	1.17	0.56	0.48
BC1	60-90	6.91	5.55	0.09	0.21	0.83	0.37	0.44
BC2	90-115	6.29	5.56	0.14	0.18	0.74	0.33	0.44
C	115-140	7.03	5.82	0.11	0.12	0.42	0.19	0.45
Pedon 10 (Jamakhandi)								
Ap	0-25	7.91	6.92	0.28	0.60	1.28	0.61	0.48
Bt1	25-50	8.06	7.03	0.22	0.42	0.85	0.37	0.43
Bt2	50-80	8.04	7.12	0.19	0.33	1.03	0.39	0.29
C	80-125	7.96	7.17	0.32	0.21	1.23	0.44	0.36

trend from surface horizon down the profile. Similar trend was observed in Devapur pedon where pH ranged from 6.27 to 7.50. In case of Kulageri pedon pH ranged from 7.16 to 8.25 where as in Kushtagi pedon the range was from 6.56 to 7.03 showing a increasing trend with depth. In Jamakhandi pedon pH varied from 7.91 to 8.06. In almost all the pedons except two an increasing trend of pH with depth was noticed.

pH measured in N KCl solution showed about 0.67 to 1.49 unit lower values than pH in soil-water suspension, in Ballary pedon.

In Budagumpa cross pedon pH (N KCl) showed 1.21 to 1.56 unit lower values than pH in soil-water suspension. In Timmapura pedon pH in N KCl was less by 0.75 to 1.58 unit. In Sandur upland 1.21 to 1.33 unit, Sandur midland 1.29 to 2.40 unit, Shivapur 0.44 to 1.38 unit, Devapur 0.91 to 1.59 unit, Kulageri cross 0.26 to 1.30 unit, Kushtagi 1.21 to 1.60 unit and in Jamakhandi 0.79 to 1.03 units lower than the pH measured in soil-water suspension of the respective pedons.

#### 4.3.2 Electrical conductivity (EC)

The data on electrical conductivity of soil-water extract is presented in Table 6. Electrical conductivity was low in all the pedons ranging from 0.05 to 0.40 dS m<sup>-1</sup>.

#### 4.3.3 Organic carbon

The data pertaining to organic carbon content of soils is presented in Table 6.

In Ballary pedon organic carbon content was 0.18 per cent in 'A' horizon and decreased to 0.12 per cent in  $Bt_2$  horizon.

In Budagumpa pedon its content decreased from 0.30 per cent in Ap horizon to 0.03 per cent in  $Bt_3$  horizon. In case of Timmapura pedon organic carbon content decreased from 0.36 per cent at the surface to 0.12 per cent in the lower horizons. A decreasing trend of organic carbon content with depth was also noticed in Sandur upland and Sandur midland pedons where organic carbon content of solum decreased from 0.69 per cent to 0.60 and 0.63 per cent to 0.45 per cent respectively. Organic carbon decreased from 0.30 per cent to 0.06 per cent in Shivapur pedon whereas in Devapur it decreased from 0.15 to 0.12 per cent. The same was the case in the solum of Kulageri pedon. Organic carbon content decreased from 0.48 to 0.18 per cent in Kushatagi solum whereas the range was from 0.60 to 0.33 per cent in the solum of Jamakhandi pedon.

#### 4.3.4 Dithionite extractable iron ( $Fe_d$ )

The data relating to dithionite extractable iron ( $Fe_d$ ) is presented in Table 6. The  $Fe_d$  content in Ballary and Budagumpa pedon varied from 0.51 to 1.38 per cent and 0.93 to 1.74 per cent respectively.  $Fe_d$  content was more in Bt horizons compared to others. In Timmapura pedon  $Fe_d$  content ranged from 0.69 to 2.64 per cent. In Sandur upland  $Fe_d$  content varied from 2.19 to 4.08 per cent whereas in midland from 1.68 to 4.28 per cent. Highest  $Fe_d$  content was observed

here among all the pedons studied. In Shivapur and Devapur pedon  $Fe_d$  content ranged from 0.54 to 1.41 per cent and 0.38 to 1.08 per cent respectively.  $Fe_d$  content of Kulageri pedon varied from 0.39 to 1.48 per cent.  $Fe_d$  content was high in Bt horizons and it decreased with depth. In Kushtagi pedon  $Fe_d$  content ranged from 0.42 to 1.33 per cent whereas in Jamakhandi pedon it varied from 0.85 to 1.28.  $Fe_d$  was nearly uniformly distributed throughout the pedon. In almost all the pedons studied, the highest  $Fe_d$  content was observed in Bt or Bw horizons compared to overlying and underlying horizons.

#### 4.3.5 Oxalate extractable iron ( $Fe_o$ )

The data on oxalate extractable iron is presented in Table 6. In Ballary solum  $Fe_o$  ranged from 0.12 to 0.18 per cent and its content decreased with depth. A wide range of 0.03 to 0.30 per cent was observed in Budagumpa solum. In Timmapura pedon  $Fe_o$  content ranged from 0.12 to 0.36 per cent. In case of Sandur upland pedon it ranged from 0.60 to 0.69 per cent and in midland solum it decreased from 0.63 to 0.45 per cent. In Shivapur and Devapur pedons the range was from 0.06 to 0.30 per cent and 0.12 to 0.45 per cent, respectively.  $Fe_o$  content ranged from 0.09 to 0.45 per cent in Kulageri solum, from 0.18 to 0.48 in Kushtagi solum and it ranged from 0.21 to 0.60 per cent in Jamakhandi pedon.  $Fe_o$  content decreased with depth in all the pedons.

#### 4.3.6 Exchangeable bases

The data pertaining to exchangeable bases is presented in Table 7. Exchangeable calcium was the the

Table 7. Data on exchangeable bases, BaCl<sub>2</sub>-TEA extractable acidity, CEC and base saturation of the soils

Horizon	Depth (cm)	Exchangeable bases				BaCl <sub>2</sub> -TEA/ extractable acidity c mol (p <sup>+</sup> ) kg <sup>-1</sup>	CEC	CEC (Sum of cations)	Base saturation (%)	
		Ca	Mg	Na	K					
1	2	3	4	5	6	7	8	9	10	11
Pedon 1 (Ballary)										
Ap	0-12	5.2	0.4	0.52	0.19	3.0		4.8	9.31	51.6
Bt1	12-29	6.8	1.0	0.64	0.19	2.8		8.9	11.43	77.9
Bt2	29-47	6.0	1.4	0.65	0.15	2.6		9.8	10.80	90.7
BC	47-76	6.0	0.8	0.66	0.11	2.0		8.8	9.57	92.0
C1	76-105	7.0	0.6	0.66	0.06	1.8		8.4	10.12	83.0
C2	105+	6.0	0.8	0.68	0.16	1.6		6.0	9.24	64.9
Pedon 2 (Budagumpa)										
Ap	0-12	6.4	2.0	0.42	0.15	0.4		9.8	12.97	75.5
B1	12-26	8.0	1.8	0.44	0.14	4.0		12.2	14.38	84.8
Bt1	26-51	8.4	1.6	0.52	0.09	3.8		13.0	14.41	90.2
Bt2	51-82	9.0	1.4	0.53	0.10	3.0		14.0	14.03	99.7
Bt3	82-104	9.2	0.6	0.60	0.11	2.8		11.2	13.31	84.1
BC	104-156	8.9	0.5	0.63	0.13	1.8		10.2	11.96	85.2
Pedon 3 (Timmapura)										
Ap	0-15	8.0	1.2	0.20	0.11	4.2		11.2	13.71	81.6
B1	15-50	8.4	1.4	0.27	0.17	4.0		12.4	14.24	87.0
Bt1	50-140	10.0	2.0	0.22	0.17	3.4		14.6	15.79	92.4
Bt2	140-180	14.0	2.4	0.26	0.18	3.2		17.2	20.04	85.8
BC	180-225	12.0	2.2	0.30	0.19	3.2		15.2	17.89	84.9
C	225-300	12.0	2.2	0.33	0.14	2.8		15.2	17.47	87.0
Pedon 4 (Sandur upland)										
Ap	0-15	12.0	1.2	0.20	0.24	4.0		15.8	17.64	89.5
BW	15-30	12.8	0.8	0.27	0.18	4.0		16.2	18.05	89.7
Pedon 5 (Sandur midland)										
Ap	0-10	16.0	1.2	0.18	0.10	4.0		20.4	21.48	94.9
Bw	10-43	17.0	1.4	0.30	0.06	3.8		21.8	22.56	96.6
C	43-81	6.0	1.8	0.33	0.04	3.6		10.0	11.77	84.9
Pedon 6 (Shivapur)										
Ap	0-12	3.0	0.6	0.56	0.14	4.0		7.6	8.30	91.5
Bt1	12-30	3.0	1.2	0.60	0.10	3.9		7.8	8.80	88.6
Bt2	30-70	6.0	2.0	0.71	0.10	3.0		11.8	11.81	99.9
C	70-108	3.6	1.8	0.74	0.11	2.4		7.2	8.65	83.2

1	2	3	4	5	6	7	8	9	10	11
Pedon 7 (Devapur)										
Ap	0-14	3.0	1.0	0.50	0.08	4.2		6.8	8.78	77.4
Bt	14-36	6.0	2.0	0.56	0.10	4.0		8.8	12.66	69.5
C	36-72	5.0	1.4	0.60	0.05	3.0		9.6	10.05	95.5
Pedon 8 (Kulageri)										
Ap	0-25	6.0	1.0	0.52	0.06	4.4		10.2	11.98	85.1
Bt1	25-60	8.4	3.6	0.71	0.09	4.2		15.0	17.00	88.2
Bt2	60-95	9.6	2.2	0.76	0.07	3.6		15.8	16.23	97.3
Bt3	95-160	11.0	2.6	0.69	0.09	3.4		17.0	17.78	95.6
BC	160-200	11.2	3.2	0.78	0.05	2.4		16.8	17.63	95.2
C	200-220	10.8	1.6	0.76	0.15	1.2		13.2	14.51	90.9
Pedon 9 (Kushtagi)										
Ap	0-20	8.8	1.2	0.59	0.11	3.4		11.8	14.10	83.6
Bt1	20-35	12.0	2.0	0.61	0.12	3.2		15.8	17.93	88.1
Bt2	35-60	11.8	3.6	0.63	0.13	3.0		17.2	19.16	89.7
BC1	60-90	11.0	3.6	0.74	0.13	3.0		16.6	18.47	89.8
BC2	90-115	12.0	1.6	0.76	0.10	2.8		16.0	17.26	92.6
C	115-140	8.0	1.2	0.78	0.10	1.6		10.0	11.68	85.6
Pedon 10 (Janakhandi)										
Ap	0-25	16.0	4.0	0.70	0.18	4.8		22.8	25.68	88.7
Bt1	25-50	17.2	4.2	0.78	0.20	4.2		22.6	26.58	85.0
Bt2	50-80	17.0	3.8	0.72	0.19	4.0		23.8	25.71	92.5
C	80-125	15.0	4.2	0.76	0.20	3.0		21.0	23.16	90.6

predominant cation. In Ballary pedon, the exchangeable calcium ranged from 5.2 to 7.0 c.mol (p+)  $\text{kg}^{-1}$  and was uniformly distributed Exchangeable magnesium ranged from 0.4 to 1.4 c.mol (p+)  $\text{kg}^{-1}$ . Both sodium and potassium were low and ranged from 0.52 to 0.68 c.mol (p+)  $\text{kg}^{-1}$  and 0.06 to 0.19 c.mol (p+)  $\text{kg}^{-1}$  respectively.

The exchangeable calcium content of Budagumpa pedon ranged from 6.4 to 9.0 c.mol (p+)  $\text{kg}^{-1}$  whereas exchangeable magnesium ranged from 0.5 to 2.0 c.mol (p+)  $\text{kg}^{-1}$ . Exchangeable sodium varied from 0.42 to 0.63 c.mol (p+)  $\text{kg}^{-1}$  and potassium from 0.09 to 0.15 c.mol (p+)  $\text{kg}^{-1}$ .

In Timmapura pedon exchangeable calcium and magnesium increased with depth. Exchangeable calcium ranged from 8.0 to 14.0 c.mol (p+)  $\text{kg}^{-1}$  and exchangeable magnesium from 1.2 to 2.4 c.mol (p+)  $\text{kg}^{-1}$ . The content of exchangeable sodium varied from 0.20 to 0.33 c.mol (p+)  $\text{kg}^{-1}$  and potassium from 0.11 to 0.19 c.mol (p+)  $\text{kg}^{-1}$ , showing a increasing trend with depth.

In Sandur upland exchangeable calcium and sodium increased with depth whereas magnesium and potassium decreased with depth. Exchangeable calcium ranged from 12.0 to 12.8 c.mol (p+)  $\text{kg}^{-1}$ , magnesium from 0.8 to 1.2 c.mol (p+)  $\text{kg}^{-1}$ , sodium from 0.20 to 0.27 c.mol (p+)  $\text{kg}^{-1}$  and potassium from 0.18 to 0.24 c.mol (p+)  $\text{kg}^{-1}$ . In Sandur midland pedon the content of exchangeable calcium ranged from 6-16 c.mol (p+)  $\text{kg}^{-1}$ , Magnesium 1.2 to 1.8 c.mol (p+)  $\text{kg}^{-1}$ . Exchangeable

sodium and potassium were low and ranged from 0.18 to 0.33 c.mol (p+) kg<sup>-1</sup> and 0.04 to 0.10 c.mol (p+) kg<sup>-1</sup>, respectively.

In Shivapur pedon exchangeable calcium and magnesium increased with depth upto third horizon and then decreased. Exchangeable calcium ranged from 3.0 to 6.0 c.mol (p+) kg<sup>-1</sup> and magnesium from 0.6 to 2.0 c.mol (p+) kg<sup>-1</sup>. Exchangeable sodium and potassium were low and uniformly distributed throughout the pedon. Similar trend was noticed in case of exchangeable bases of Devapur pedon where exchangeable calcium varied from 3.0 to 6.0 c.mol (p+) kg<sup>-1</sup> and magnesium from 1.0 to 2.0 c.mol (p+) kg<sup>-1</sup>. Exchangeable sodium and potassium ranged from 0.50 to 0.60 c.mol (p+) kg<sup>-1</sup> and from 0.05 to 0.10 c.mol (p+) kg<sup>-1</sup> respectively.

The exchangeable calcium ranged from 6.0 to 11.2 c.mol (p+) kg<sup>-1</sup> and magnesium from 1 to 3.6 c.mol (p+) kg<sup>-1</sup> in Kulageri cross pedon. A fairly uniform distribution of sodium and potassium was seen throughout the pedon. Exchangeable sodium content ranged from 0.52 to 0.72 c.mol (p+) kg<sup>-1</sup> and Potassium from 0.05 to 0.15 c.mol (p+) kg<sup>-1</sup>.

Distribution of exchangeable cations in Kushtagi followed the trend of Kulageri pedon. Exchangeable calcium content varied from 8 to 12 c.mol (p+) kg<sup>-1</sup> and magnesium from 1.2 to 3.6 c.mol (p+) kg<sup>-1</sup>. Exchangeable sodium and potassium were low and ranged from 0.59 to 0.78 c.mol (p+) kg<sup>-1</sup> and 0.10 to 0.13 c.mol (p+) kg<sup>-1</sup> respectively. In Jamakhandi pedon the content of exchangeable calcium ranged from 15.0 to 17.2 c.mol

(p+)  $\text{kg}^{-1}$  and magnesium from 3.8 to 4.2 c.mol (p+)  $\text{kg}^{-1}$ . Exchangeable sodium and potassium ranged from 0.70 to 0.78 c.mol (p+)  $\text{kg}^{-1}$  and 0.18 to 0.20 c.mol (p+)  $\text{kg}^{-1}$  respectively and they were uniformly distributed throughout the pedon.

#### 4.3.7 BaCl<sub>2</sub> = TEA Extractable acidity

The data on BaCl<sub>2</sub> - TEA extractable acidity is given in Table 7. In Ballary pedon extractable acidity ranged from 1.6 to 3.0 c.mol (p+)  $\text{kg}^{-1}$  and constantly decreased with depth. In Budagumpa pedon it ranged from 1.8 to 4.0 c.mol (p+)  $\text{kg}^{-1}$ . It was uniformly distributed in top 51 cm and sharply decreased in C horizon. Extractable acidity of Kudalogi pedon ranged from 2.8 to 4.2 c.mol (p+)  $\text{kg}^{-1}$  and it decreased with depth. In Sandur upland pedon a uniform distribution of extractable acidity was noticed (4 c.mol (p+)  $\text{kg}^{-1}$ ) where as it ranged from 3.6 to 4.0 c.mol (p+)  $\text{kg}^{-1}$  in midland showing a fair uniform distribution throughout the pedon.

In Shivapur and Devapur pedon it ranged from 2.4 to 4.0 c.mol (p+)  $\text{kg}^{-1}$  and 3.0 to 4.2 c.mol (p+)  $\text{kg}^{-1}$  respectively. Extractable acidity decreased with depth in both the pedons. Extractable acidity of Kulageri pedon ranged from 1.22 to 4.44 c.mol (p+)  $\text{kg}^{-1}$ , Kushtagi from 1.6 to 3.4 c.mol (p+)  $\text{kg}^{-1}$  and in Jamakhandi pedon from 3.0 to 4.8 c.mol (p+)  $\text{kg}^{-1}$ . In general a decreasing trend of BaCl<sub>2</sub>-TEA acidity was noticed in all the pedons.

#### 4.3.8 Cation exchange capacity (CEC)

The data pertaining to cation exchange capacity of soils is presented in Table 7.

In Ballary pedon CEC ranged from 4.8 to 9.8 c.mol (p+)  $\text{kg}^{-1}$ . Its content increased upto  $\text{Bt}_2$  horizon and then decreased. Similar trend was observed in case of Budagumpa pedon where CEC ranged from 9.8 to 14.0 c.mol (p+)  $\text{kg}^{-1}$ . In Timmapura pedon CEC ranged from 11.2 to 17.2 c.mol (p+)  $\text{kg}^{-1}$ . Its content increased upto 120 cm and then decreased.

In case of Sandur upland CEC was almost uniform in both the horizons ranging from 15.8 to 16.2 c.mol (p+)  $\text{kg}^{-1}$  whereas in midland it ranged from 10.0 to 20.4 c.mol (p+)  $\text{kg}^{-1}$ . It increased upto 43 cm and sharply decreased in C horizon.

In Shivapur and Devapur (k) pedons CEC ranged from 7.2 to 11.8 c.mol (p+)  $\text{kg}^{-1}$  and 6.8 to 9.6 c.mol (p+)  $\text{kg}^{-1}$  respectively. An increasing trend was observed upto 70 cm depth.

CEC increased upto  $\text{Bt}_3$  horizon and then decreased in Kulageri pedon. The range of CEC was from 10.2 to 17.0 c. mol (p+)  $\text{kg}^{-1}$ , its content increased upto 60 cm and decreased. The CEC of Jamakhandi pedon varied from 21.0 to 23.8 c.mol (p+)  $100 \text{ kg}^{-1}$ . CEC was high in B horizon and decreased in C horizon.

**CHAPTER - V**

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**DISCUSSION**

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## V. DISCUSSION

Ten red soil pedons from Northern Dry Zone (Agroclimatic Zone 3) in Karnataka were studied for their morphological features in field and horizon samples were analysed in the laboratory for physical and chemical properties, with the objectives to understand their properties, genesis and to classify them according to United States Soil Taxonomy. Geology and topographical situations varied among different sites. Among the ten pedons, seven pedons were selected from granite area, two from schist and one from sandstone area.

### 5.1 Soil properties

#### 5.1.1 Morphological features

Horizon differentiation was mainly based on colour, texture and content of coarse fragments. A wide variation was observed in solum depths of soils developed on different parent rocks and physiographic situations. Upland soils were shallower, whereas midland soils were comparatively deeper. Solum depths of Ballary, Shivapur, Devapur, Sandur upland and midland pedons were shallower compared to those of Budagumpa, Timmapur, Kulageri, Kushtagi and Jamakhandi pedons. Depth of solum is directly related to weatherability of the parent rocks as a case, in Kulageri pedon deeper solum is due to presence of sandstone which is easily weatherable. The depth of solum is also influenced by topographical features of the area, as it

controls erosion and differential transport of eroded materials.

Ballary pedon exhibited redder hue (2.5 YR) throughout the solum except in the surface horizon as free iron content has increased with depth. Similar observations were recorded in Timmapura and Kushtagi pedons.

In Budagumpa redder hue (2.5 YR) was exhibited throughout the solum. Sandur upland, Shivapur, Devapur and Jamakhandi pedons exhibited yellower hue throughout the solum which may be probably due to high content of organic matter and irrigation of land since many years. In Kulageri pedon hue remained redder throughout the solum because of ferruginous nature of sandstone.

The structure was predominantly subangular blocky in all the pedons and was weak to moderately developed. The structural development of Kulageri pedon was not apparent due to large amount of gravels. Shivapur, Sandur upland and midland pedons exhibited comparatively good structure because of less coarse fragments. Due to more amount of organic carbon and less gravel content structural development was good in surface soils in all the pedons. Similar observations were made by Krishnamurthy (1993).

The consistency of soils did not vary much among the different pedons studied. Dry consistency varied from slightly hard to hard and moist consistency from friable to very

friable. The friable consistency indicates good soil-water-air relationship in these soils. The plasticity of the soils varied from nonplastic to plastic and stickiness from slightly sticky to sticky when wet. This variation from surface to subsurface is related to increase in clay content.

#### 5.1.2 Particle size distribution

Among the different pedons studied, the content of coarse fragments was less in Sandur midland and Shivapur pedons, followed by Devapur, Jamakhandi and Budagumpa pedons. The gravel content was high in Timmapura, Kulageri and Kushtagi pedons. The coarse fragments were considerably large in size and irregular in outline in Timmapura pedon compared to Kulageri and Kushtagi pedons due to the colluvial nature of the parent material. Kulageri pedon consisted mostly fragments of ferruginous sandstone, whereas quartz fragments resistant to weathering constituted the gravel content in Kushtagi.

Sand size particles were dominant in all the pedons comprising more than 50 per cent of the mineral matter. Of the different sand fractions very coarse sand content predominated over others in all the pedons from granite gneissic area. Very coarse, coarse and medium sand content were nearly same in Jamakhandi pedon (Murthy *et al.*, 1982).

Particle size distribution of soils revealed that majority of the soils were sandy to sandy loam in texture in the surface and sandy loam to sandy clay loam in B horizons due

to illuviation of clay along with percolating water (Buringh, 1970).

Clay content was high in Bt horizons of Ballary and Budagumpa pedons because of high amount of gravels in Bt horizon, which favoured physical mobility of the fine fraction due to percolating water (Bhargava *et. al.*, 1973). In Sandur pedons the degree of clay increase in Bw horizons was not appreciable when compared to other pedons. The clay content in Ap horizon was highest in these pedons, a property associated with schistose parent rock which yields high clay upon weathering. In Kulageri and Kushtagi pedons, clay content was highest in Bt and B horizons respectively, because of high amount of coarse fragments present in those horizons, which have favoured the translocation of clay from overlying horizons. The distribution of fine clay in all the pedons studied followed the trend of clay (Fig 2 to 7). Fine clay content is highly and positively correlated with clay ( $r = 0.8957$ ) whereas the correlation was negative between clay and sand ( $r = -0.8874$ ). Similar observations were made by Parvatappa and Raj (1968). The silt content and distribution was uniform in the soils derived from schist compared to soils derived from granite.

The sand content and distribution in soils varied depending upon the type of parent material from which they have been derived. As a case, sand content was low in Sandur pedons compared to others. Finer sand fractions contributed to the

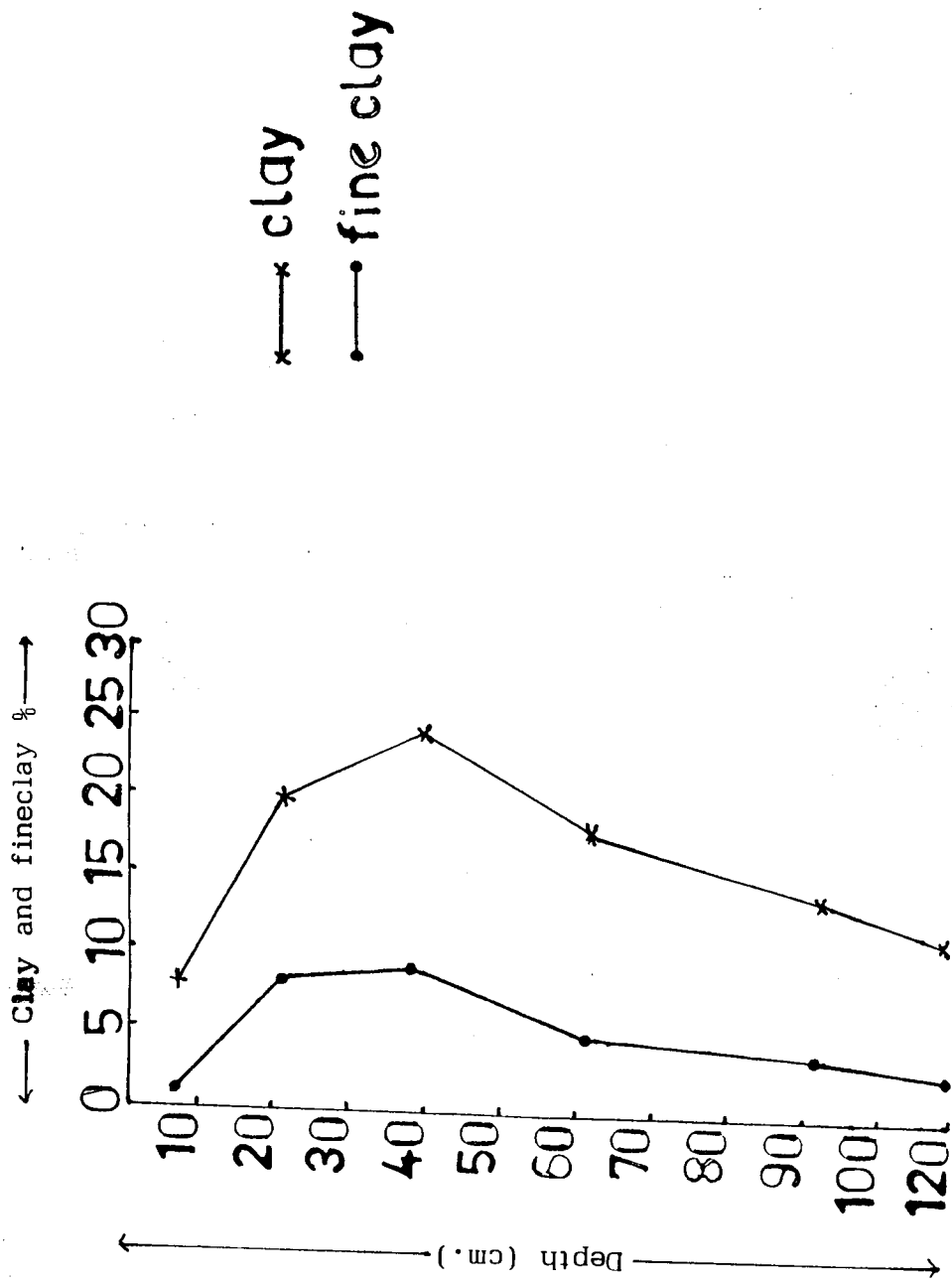


Fig 2 Clay and fine clay distribution in Ballary pedon

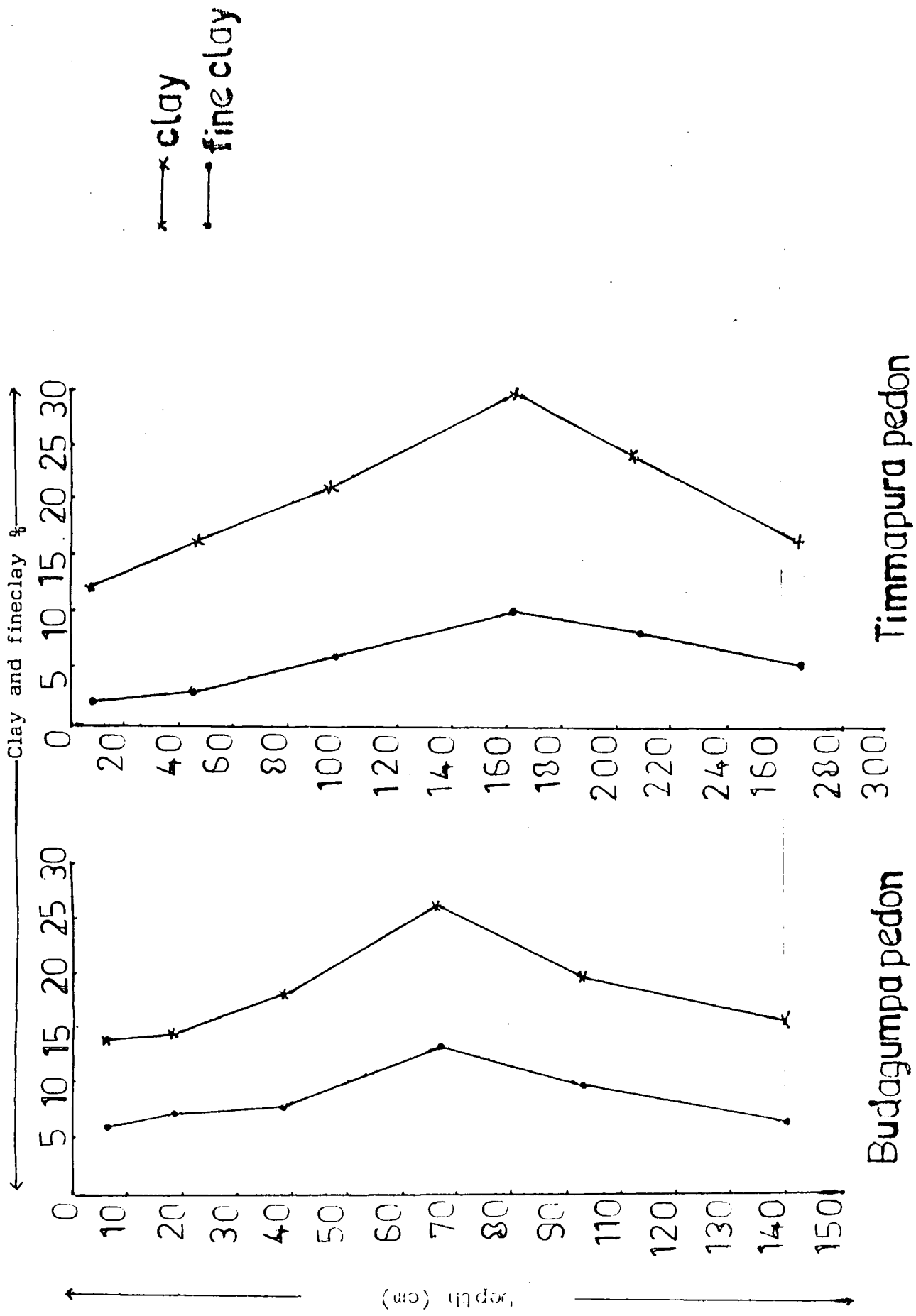


Fig 3 Clay and fineclay distribution in Budagumpu and Timmapura pedons

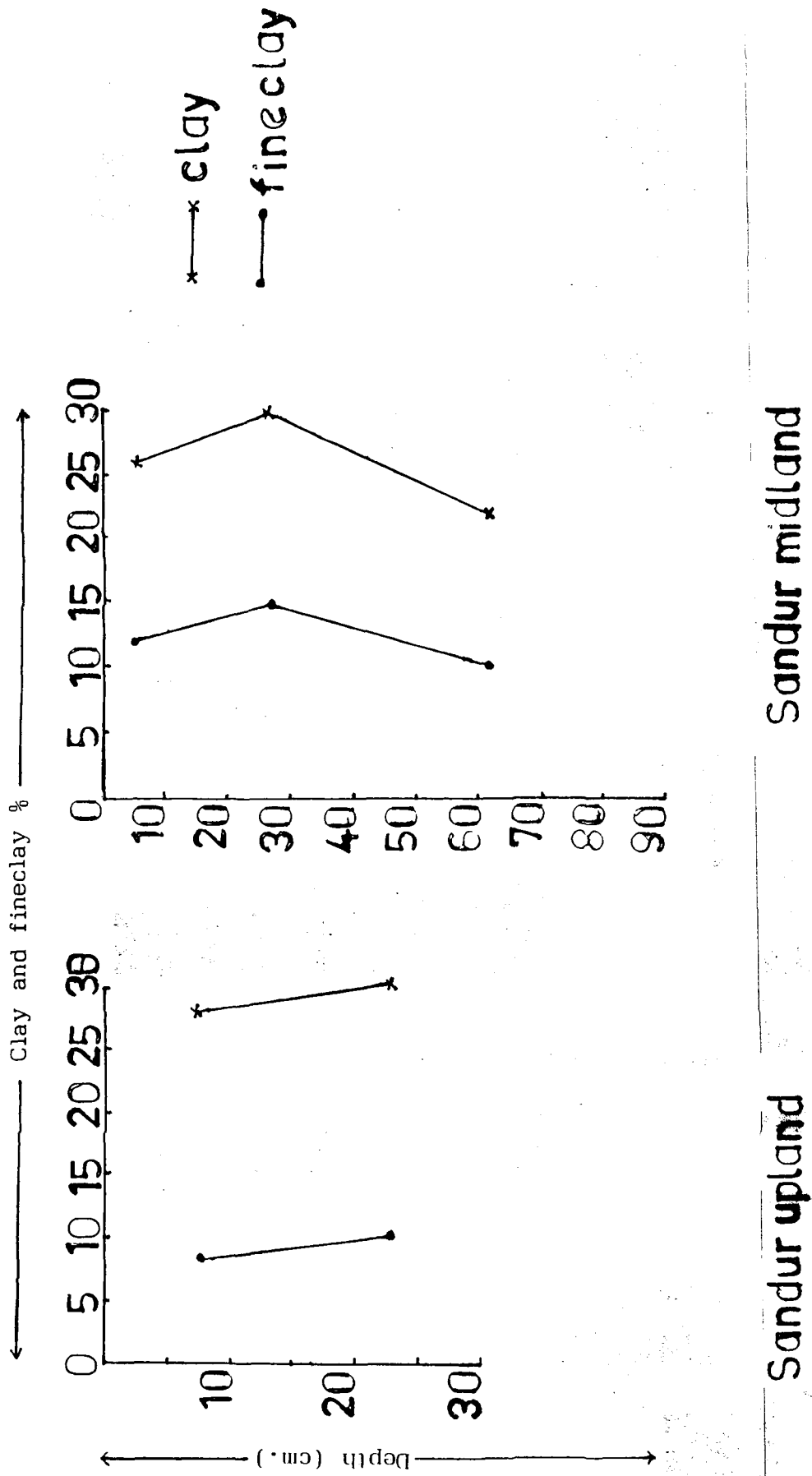


Fig 4 Clay and fine clay distribution in Sandur pedons



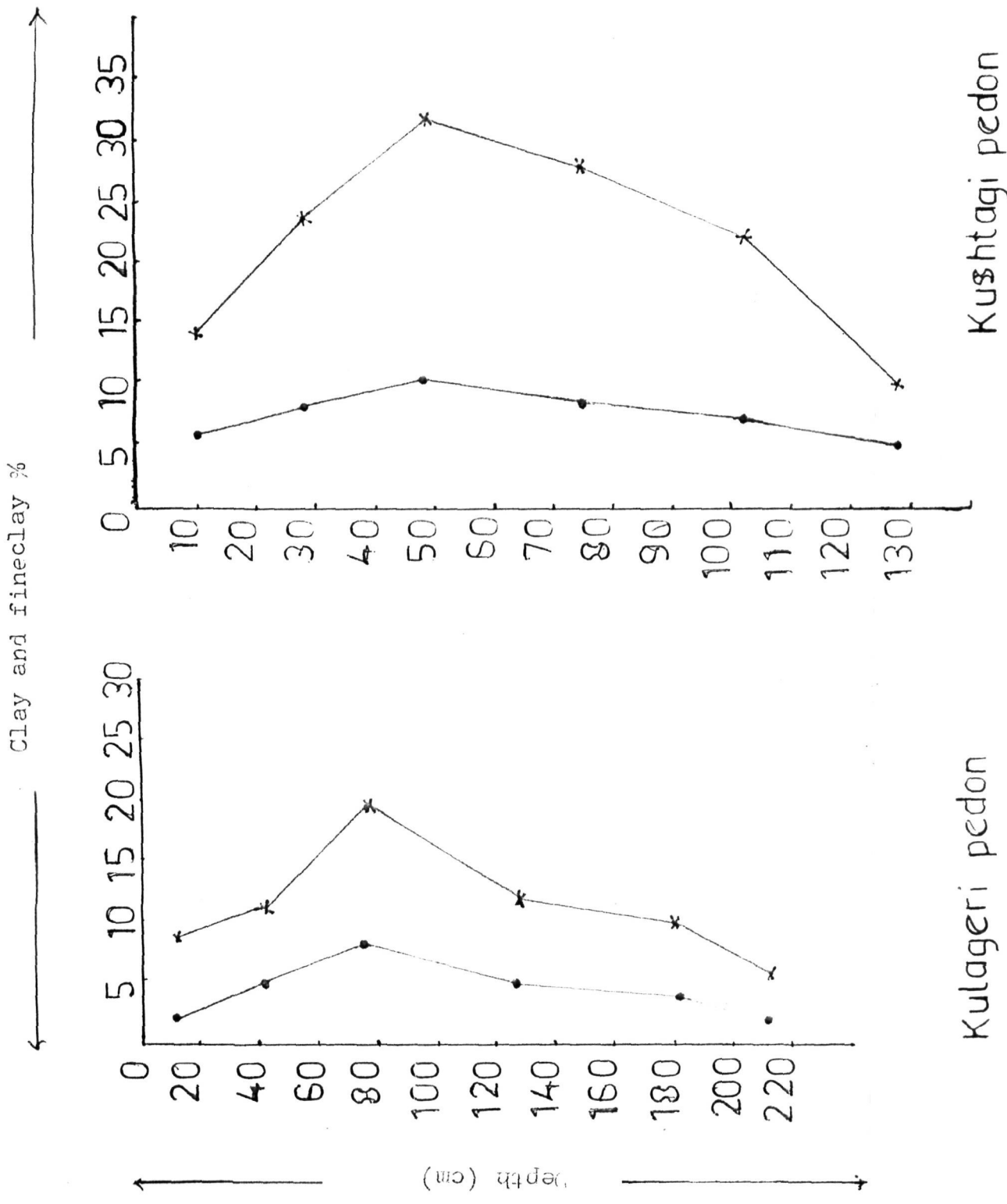


Fig 6 Clay and fineclay distribution

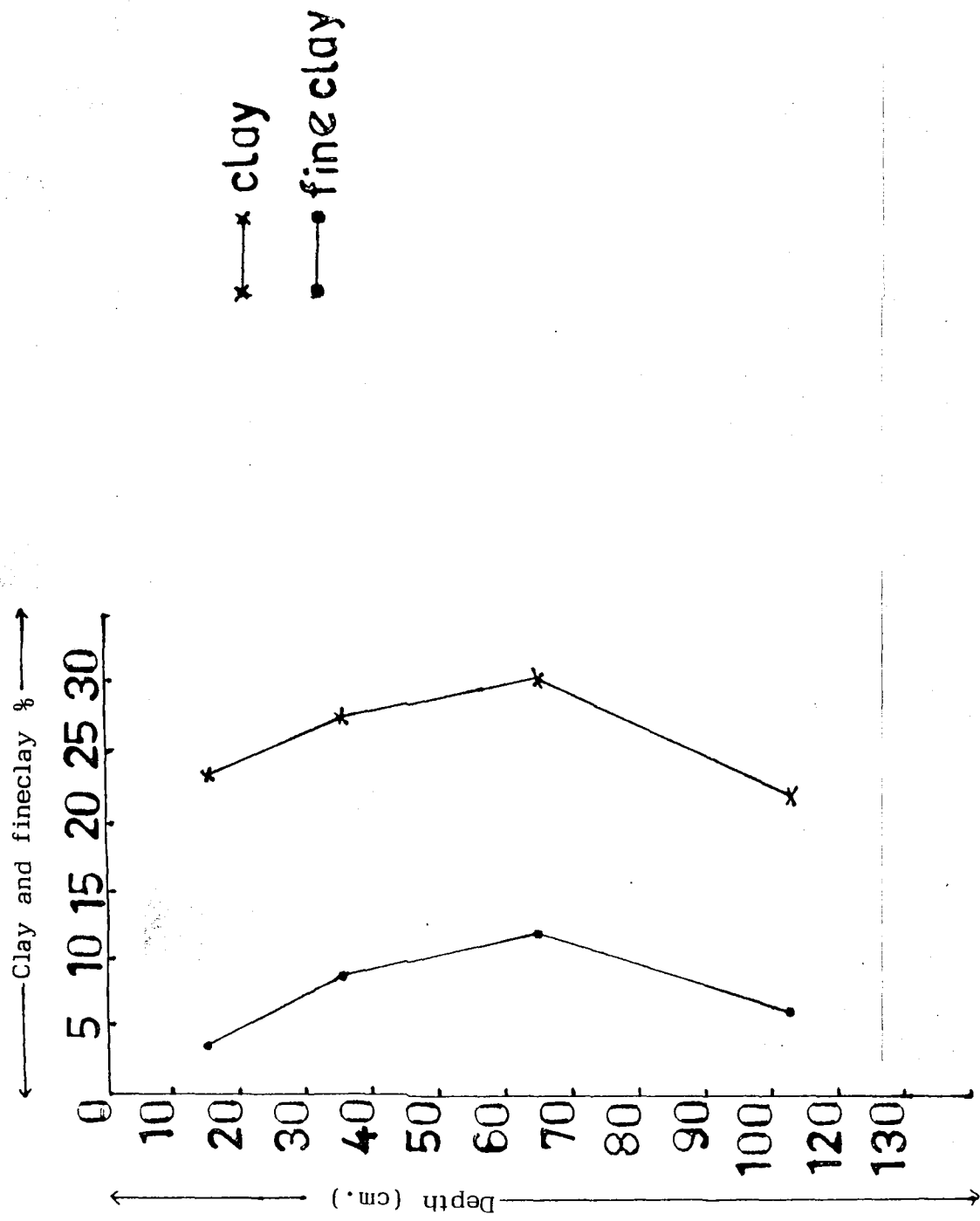


Fig 7 Clay and fineclay distribution in Jamakhandi pedon

bulk of the total sand in soils derived from schist than those derived from granite, where coarser sand fractions constitute major share in the total sand.

### 5.1.3 Physical properties

Bulk density of Bt horizons in Ballary, Budagumpa, Sandur midland and Shivapur pedons was relatively less, because of more amount of clay in those horizons. Childyal and Satyanarayana (1965) reported an inverse relationship between clay content and bulk density. However, it was not possible to collect bulk density samples upto Bt horizon in other pedons.

Moisture retention at 33 kPa was highest in 'Bw' horizon of Sandur midland pedon and lowest in surface horizon of Timmapura pedon. The trend of moisture retention both at 33 kPa and 1500 kPa followed that of clay. Water retention increased in all cases to a great extent down the profile both at 33 kPa and 1500 kPa.

At 1500 kPa, the correlation was of greater degree ( $r = 0.758$ ) than with 33 kPa ( $r = 0.730$ ). This is because of the reason that, besides texture, structure influences 33 kPa water retention, whereas 1500 kPa water retention is mainly governed by the surface area offered by the clay. In Sandur upland and midland pedons, the available water was comparatively more even in the lower horizons, as these soils are derived from schist. The findings of moisture retention characteristic and its relation with the texture of the soil are in agreement with the results of Ali *et al.* (1966) and Krishnamurthy (1993).

Surface area of the soils closely followed the trend of clay distribution in the different pedons studied. Among all the pedons, Sandur upland and midland soils exhibited highest surface area followed by Kushtagi pedon due to their high content of clay. The surface area of Bt or Bw horizon was more in all the pedons due to clay accumulation. The results of surface area indicated that these pedons contained non expanding layer silicates such as kaolinite and micas, which have only external surfaces. The results of surface area are in agreement with the results of Krishnamurthy (1993).

#### 5.1.4 Chemical properties

The pH of the soils measured in soil-water suspension exhibited a wide range in pH and varied from mildly acidic to mildly alkaline. In Budagumpa and Sandur midland pedons, the pH was neutral to alkaline. Due to less rainfall most of the bases were not leached. In Kulageri pedon pH sharply increased in 'C' horizon due to presence of calcium carbonate at that depth. Ballary pedon exhibited comparatively acidic pH among all the pedons studied as it is more prone for leaching of bases due to its sandy texture and physiographic location. In all the pedons studied the pH of soil increased with depth. This is due to increase of base saturation with depth. Perriera *et al.* (1988) and Krishnamurthy (1993) observed similar trend.

The pH of soil measured in 1 N KCl increased with depth and followed closely the trend observed for pH in water.

The difference between pH measured in KCl and that measured in water was negative in all the pedons. This indicates that these pedons contain appreciable amounts of silicate minerals with relatively constant charge. The electrical conductivity of soils measured in soil-water extract was low in all the pedons and it did not vary much. The low electrical conductivity indicates that soluble salts are leached.

The organic carbon content of surface soil was greater than the subsurface soils. The organic carbon content of Ballary, Budagumpa, Timmapura, Shivapur, Devapur, Kulageri and Kushtagi pedons was low, as a result of sparse vegetative cover and very rapid oxidation of organic matter facilitated by the high temperature regimes prevailing in the regions (Bharghava *et al.*, 1973). Organic carbon content of surface horizons of Jamakhandi, Sandur upland and midland pedons was comparatively more as these soils are under well irrigation and have comparatively more thicker vegetation. Organic carbon content gradually decreased with depth indicating the maturity of the pedons (Sahu *et al.*, 1990, Satyanarayana and Biswas, 1970).

Dithionite ( $Fe_d$ ) and Oxalate ( $Fe_o$ ) extractable iron reflect important pedogenic processes and thus help to differentiate between great soil groups (Blume and Schwertman, 1969).  $Fe_d$  content of Ballary pedon was low because of low organic carbon content and less clay content. The content of  $Fe_d$  was highest in Sandur midland and upland pedons among all

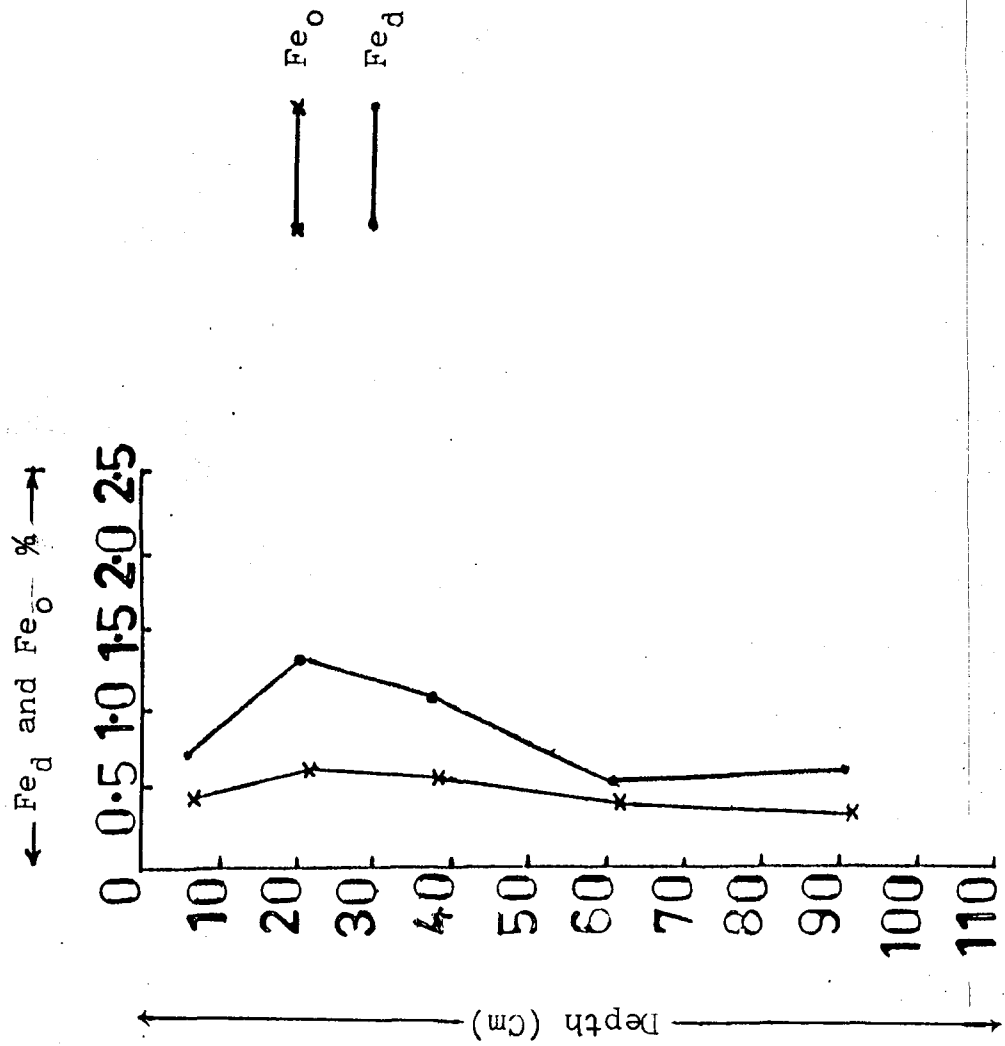


Fig 8 Fe<sub>d</sub> and Fe<sub>o</sub> Distribution in Bellary pedon

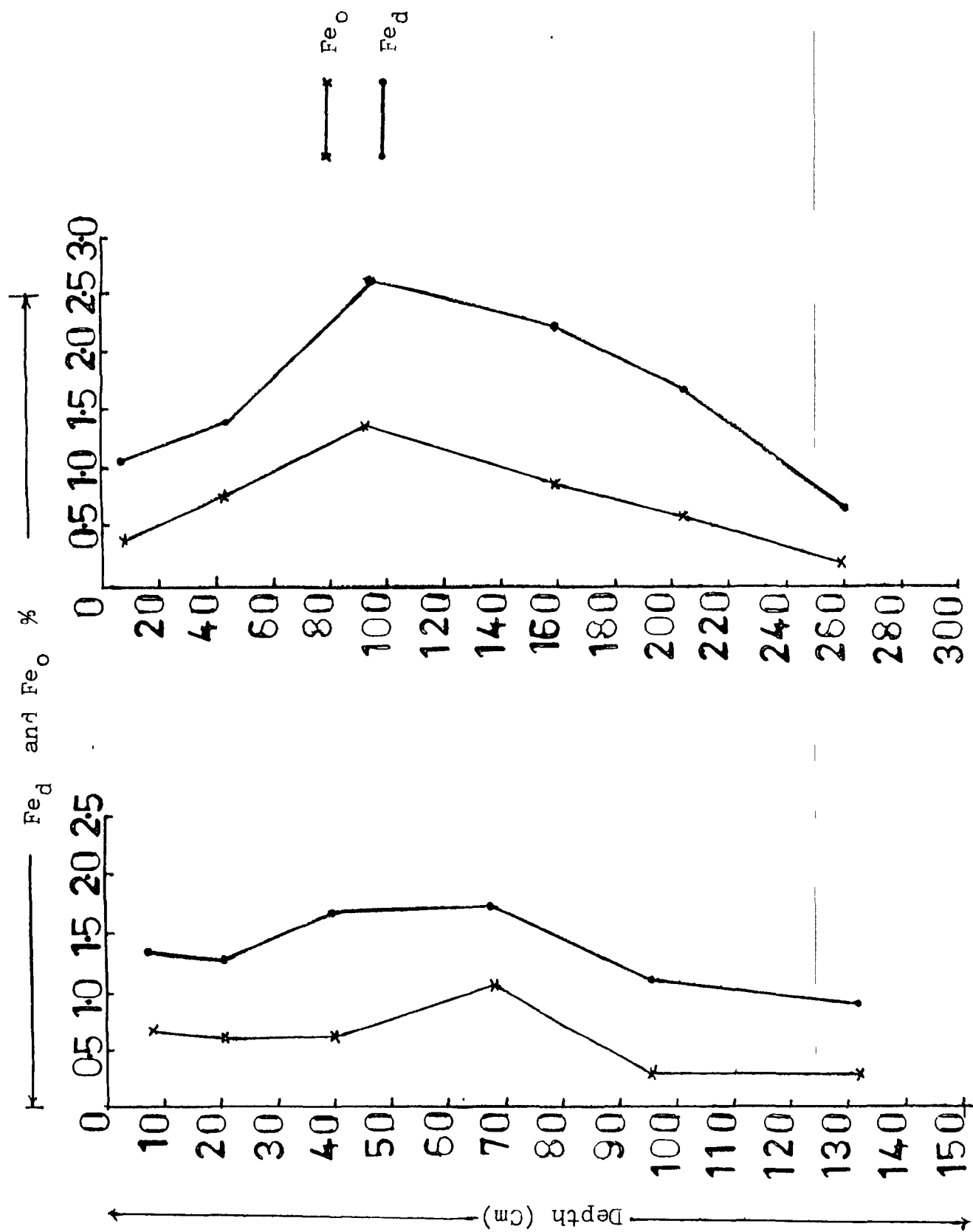


Fig 9 Fe<sub>D</sub> and Fe<sub>O</sub> Distribution in Budagumpa and Timmapura pedons

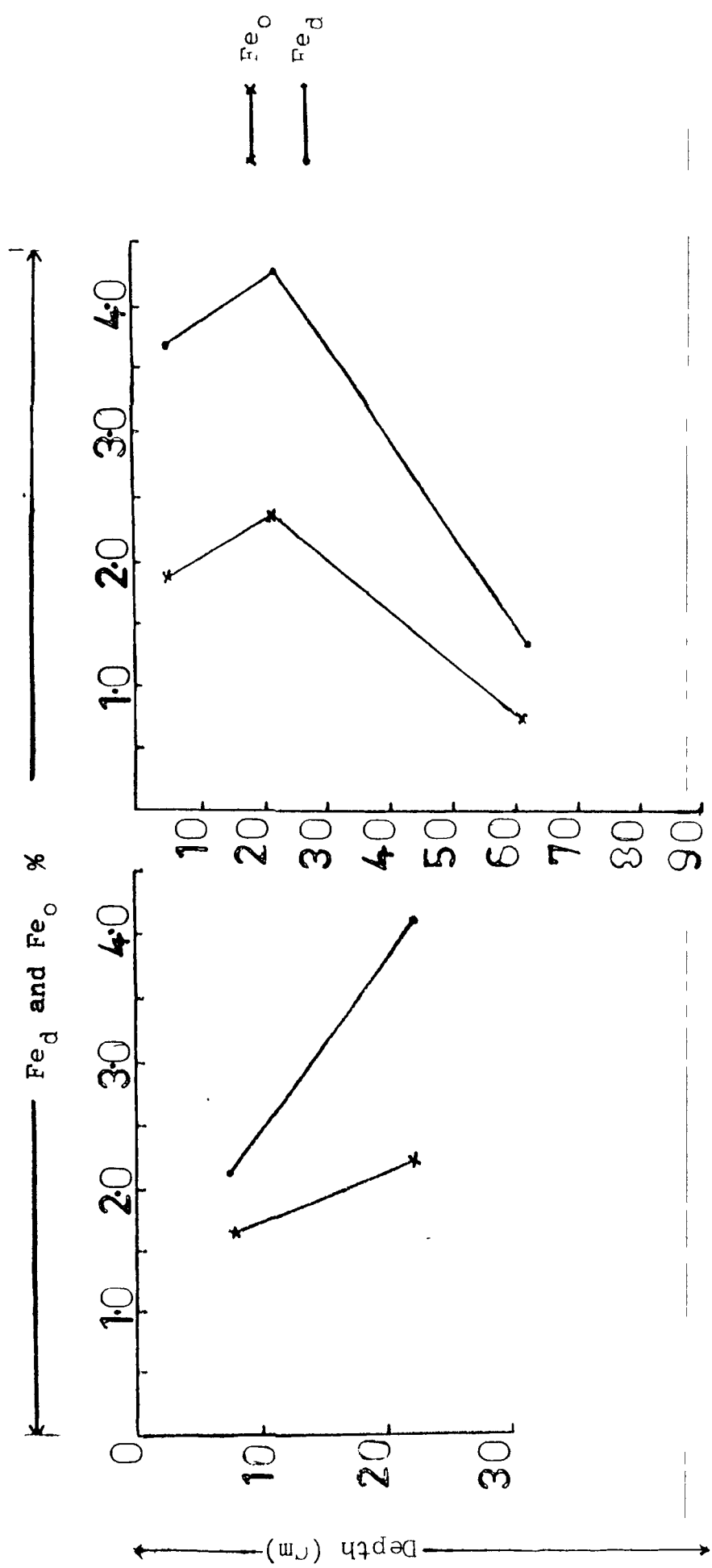


Fig 10 Fe<sub>d</sub> and Fe<sub>o</sub> Distribution in Sandur pedons

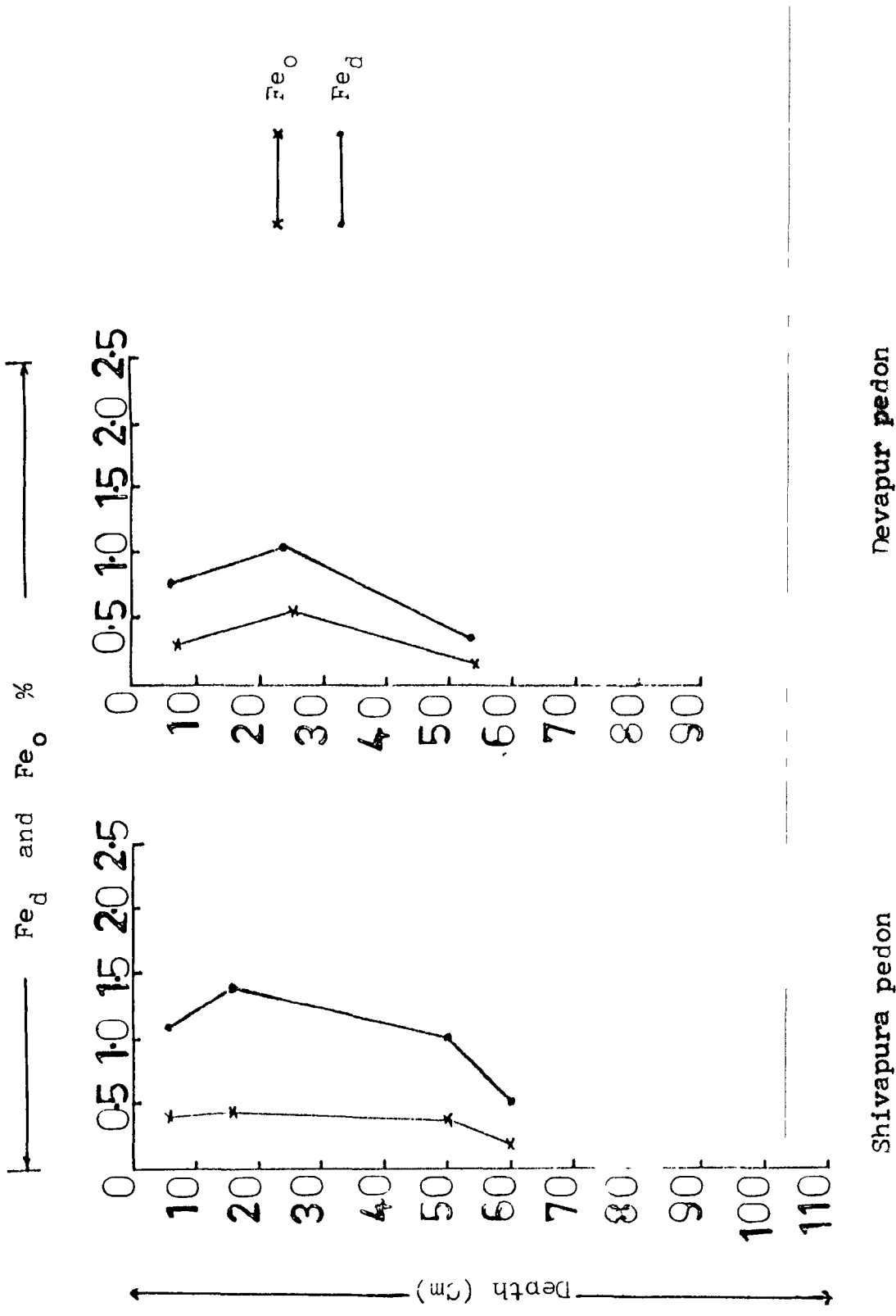
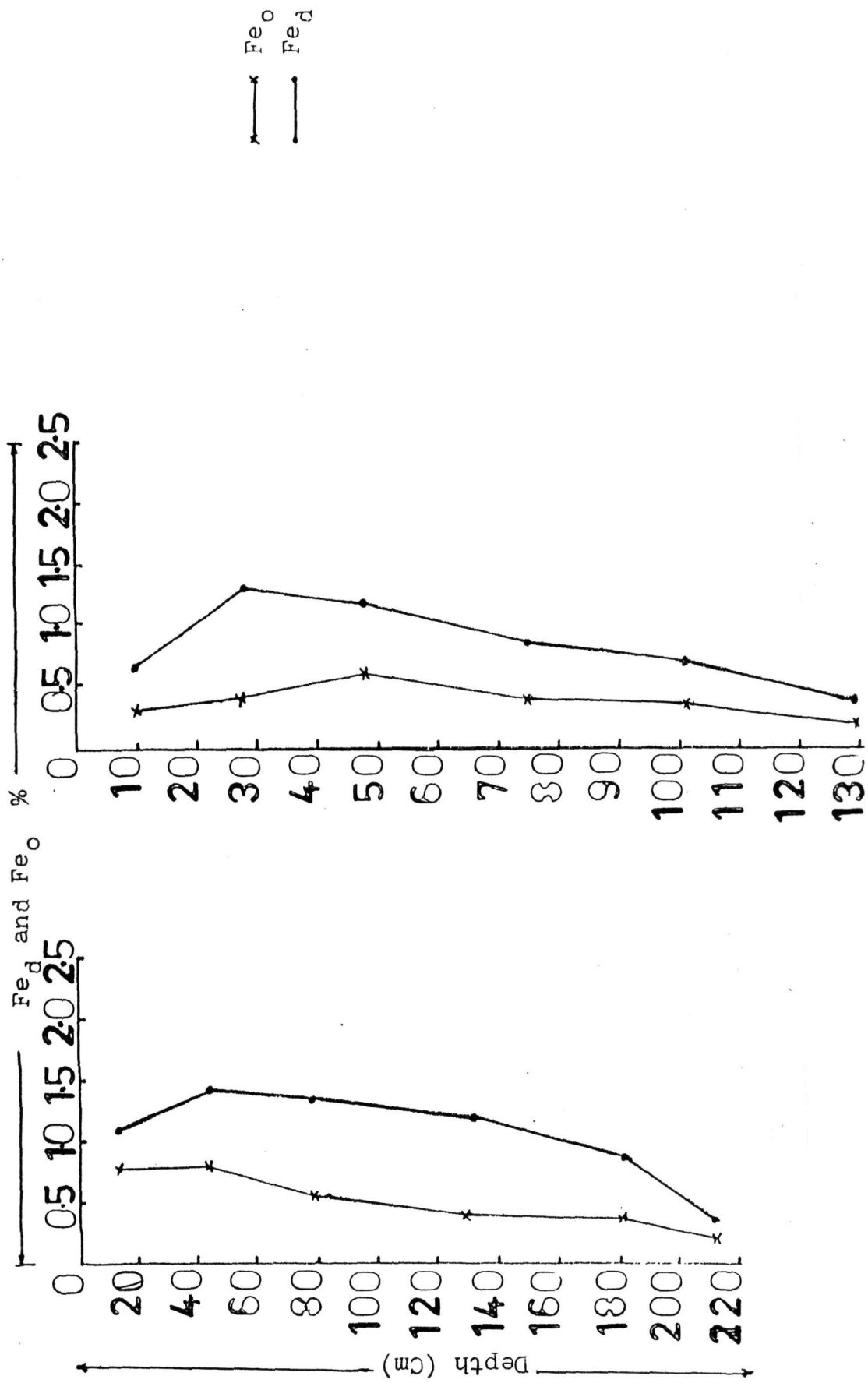


Fig 11 Fe<sub>d</sub> and Fe<sub>o</sub> Distribution in Shivapura and Devapur pedons



Kulageri pedon

Kushtagi pedon

Fig 12 Fe<sub>D</sub> and Fe<sub>O</sub> Distribution in Kulageri and Kushtagi pedons

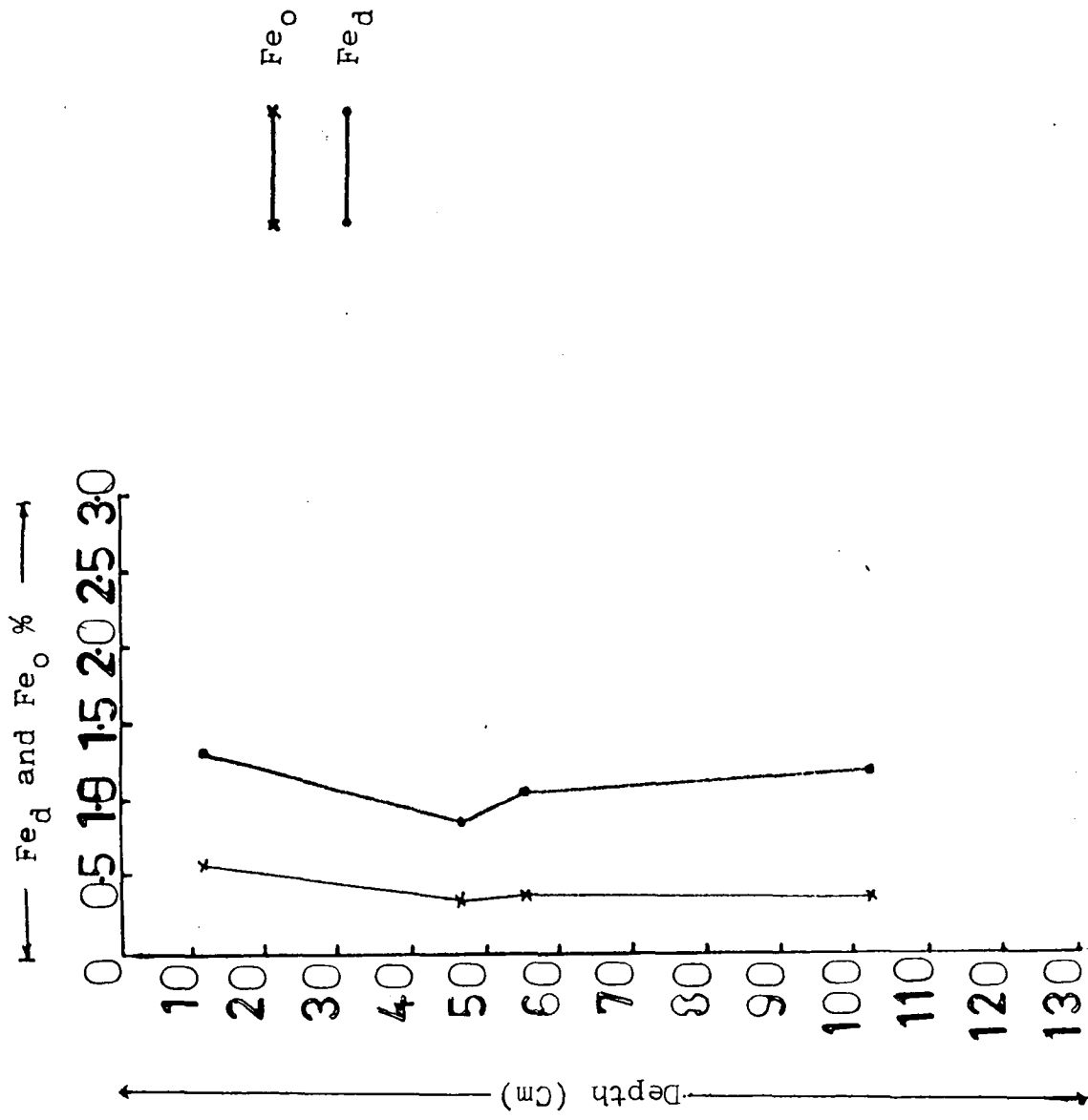


Fig 13 Fe<sub>D</sub> and Fe<sub>O</sub> Distribution in Jamakhandi pedon

the pedons studied, due to high weathering, more clay and organic carbon content. Fed content was relatively more in Kulageri pedon because of ferruginous nature of soils.

Bt horizons of Timmapura, Budagumpa, Shivapur and Devapur pedons contained high Fed than underlying or overlying horizons due to more clay content, which moved along with clay. More Fed suggests that more amorphous iron had been transformed to crystalline iron. The content of clay positively correlated with Fed ( $r = 0.577$ ) so also the organic matter contents ( $r = 0.478$ ). The Fed comprises iron extracted from iron bearing secondary minerals and amorphous iron or stable allophanes (Mc Keague and Day, 1966). It is an indicator of depth of weathering and can also be used as an indicator of depth of argillic horizon. Maximum Fed was observed in Bt horizons of all the pedons under study due to movement of iron along with clay. Similar observations were made by Krishnamurthy (1993) in Alfisols from North Karnataka and Raghunathan and Bhonsle (1993) in Alfisols from Goa, Karnataka and Pondicherry.

The ratio of  $Fe_d$  to clay was high in Sandur pedons derived from schist when compared to other soils derived from granitic parentage; and the ratio was almost double in schist derived soils.  $Fe_o/Fe_d$  ratio was high in surface horizons of all the pedons. The ratio of  $Fe_o/Fe_d$  termed as "activity ratio", indicates the degree of aging or crystallinity of free iron oxides (Blume and Schwertman, 1969).

Among the different exchangeable cations, calcium was the dominant one in all the pedons. (Satyanarayana and Biswas, 1970), and the content of potassium was lowest. The concentration of exchangeable cations increased with the depth in all the pedons. The general order of preponderance of cations was  $\text{Ca} > \text{Mg} > \text{Na} > \text{K}$ . Although the relative proportions of these cations varied in these soils, the trend usually remained unaltered (Bhargava *et. al.*, 1973).

$\text{BaCl}_2$ -TEA extractable acidity decreased with depth in all the pedons. The decrease in extractable acidity with depth may be due to decrease in organic matter content ( $r = 0.704$ ). Similar observations were made by Ananthanarayana and Perur (1973), Krishnamurthy (1993) and Rudramurthy (1994) as total acidity is related to organic matter content and clay content due to the buffering action.

The cation exchange capacity and base saturation are important criteria for soil classification. Cation exchange capacity by sum of cations (exchangeable bases plus  $\text{BaCl}_2$ -TEA extractable acidity) was greater than that determined by  $\text{NH}_4\text{OAC}$  method which tends to support the preponderance of pH dependent exchange sites in the soil (Sen *et al.*, 1993). The CEC of Ballary and Devapur was low due to their sandy texture or low clay content. CEC values were relatively high in Bt horizons due to increase in clay content. Cation exchange capacity increased with depth in all the pedons and followed the trend of clay. CEC is largely governed by clay content

(Krishnamurthy, 1993). There was a positive correlation between the two ( $r = 0.408$ ).

## 5.2. Pedogenesis

Based on the soil properties, soil forming factors and the important pedogenic processes operative in these soils are discussed here.

### Soil Physiography relationship

The soil physiography relationship is important as it controls the distribution of the soil in the landscape. In undulating to rolling landscape of Ballary and Budagumpa, and very gently undulating to rolling mid-upland to undulating upland type of landscape in Timmapura, Shivapur, Devapur, Sandur upland and midland, there exists a clear relationship between soil and physiography. The soils were shallow to moderately deep in upland and deep to very deep in midland situation at all the sites. Erosion and redistribution of weathered materials have been responsible for the observed properties. The content of finer constituents especially the clay particles is comparatively higher in the pedons situated in the lower element of the landscape (Biswas and Gawande, 1962). The translocation of clay vertically downward in the profiles situated in the higher element of the landscape was observed. In granitic landscape of Muddebihal taluka in Bijapur district the soils with argillic horizon were observed both on mesas and uplands (RhodustalFs) and on pediments (HaplustalFs) (NBSS and LUP, 1982). In the present study, in

majority of the pedons present AP-Bt-BC-C sequence. In Sandur pedon however, a Bw horizon is present both in upland and midland situations. Appreciable amount of  $\text{CaCO}_3$  in Jamakhandi pedon is related to lack of adequate leaching due to its location in a valley. The calcium carbonate content was minimum in the surface horizons (1.0 to 3.2 per cent) and it sharply increased to 8.2 per cent in 'C' horizon.

#### Role of parent material in pedogenesis

Parent material is an important factor in pedogenesis that influences physical, chemical, physico-chemical and mineralogical properties of soil in areas receiving less rainfall.

Ballary, Budagumpa, Timmapura, Shivapur, and Devapur pedons which have granitic parentage, are characterised by markedly low silt content and relatively high sand content. Coarse fragments are more in the lower solum at transition and 'C' horizons, which largely comprise of unweathered fragments of parent material. The influence of parent rock is also seen in Sandur upland and midland soils. These soils are characterised by lesser sand content and comparatively higher silt content with yellowish-red to red colour and sandy clay loam texture. The property of schist is also highlighted in properties like high pH and high water holding capacity. These soils are also characterised by high  $\text{Fe}_d$  content.

In Kulageri, the surface and 'C' horizons are dominated by high sand content compared to other horizons. However, in the subsurface there is accumulation of clay. Though it is believed that the sandstones of this area are quartzitic in nature and can not form clay. The clay must have derived from shale beds within sandstones (Foote, 1876). The uniformly red colour of 2.5 YR hue in this pedon is also due to the ferruginous nature of these sandstones. As per the findings of Krishnamurthy (1993) the heavy mineral suite in this area is relatively high and predominantly contains haematite.

Jamakhandi soils are formed from alluvium derived from sandstone and quartzite. Gravel content was minimum in the surface horizons and increased in subsurface horizons. The soils also contained calcium carbonate ranging from 1.0 to 8.2 per cent, the highest being in the 'C' horizon. Clay content increased with depth and its accumulation was high in Bt<sub>2</sub> horizon.

It is clear from the observations that parent material had a profound influence on the genesis of these soils.

#### Role of climate

Climate is often considered to be a major factor determining the formation of the great soil group. A secondary role of climate is seen in the pedogenesis of soils under study. Of the different constituents of climate like

temperature humidity, wind, evapotranspiration, duration of sunshine and others, rainfall and temperature are important, which affect soil formation . Since all the soils under study are selected from dry zone characterised by low rainfall and high temperature their influence on different soil properties is seen to some extent. Low organic carbon content, higher base saturation and lower moisture retention values are some of the soil characters influenced by low rainfall and high temperature, in almost all soils. Slightly alkaline pH and comparatively low  $\text{BaCl}_2$ -TEA acidity are the other soil properties influenced by milder climate of the region.

#### Pedogenic processes

In different pedons under study, the important pedogenic process is illuviation of clay. Clay illuviation is favoured by the porous light textured surface horizons in all the pedons. The conditions are favourable for clay translocation and accumulation in the subsurface as enumerated in Soil Taxonomy (Soil Survey Staff, 1975). The process of argillation is most evident in older soils of semiarid and arid regions and it comprises of three sets of processes such as mobilization or dispersion, transportation or translocation and accumulation of the clay. Each of these process require specific soil conditions and it is only when all these are optimal that an argillic horizon is formed, as a case argillation is the result of sudden wetting of dry soil, causing appreciable rise in pH and temporary mobilization of clay, thus mobilized clay is translocated over a short distance

by percolating water and accumulates in lower horizon, on ped surface, as pores get dried because of low precipitation (Buringh 1970). The clay translocation is evidenced by presence of clay skins on ped faces in all pedons except Sandur midland and upland. However, they were thin patchy and occurred as sand bridges. Nikiforoff (1937) postulated that the presence of argillic horizon under semiarid conditions was mostly due to the formation of clay minerals *in situ*, as seen in Kulageri pedon, derived from sandstone which is quartzitic in nature and can not form clay. However Buol and Hole (1959) believes that both illuviation and *in situ* formation are responsible for the development of an argillic horizon under semiarid conditions.

The morphological expression was not commensurate with the magnitude of clay increase between eluvial and illuvial horizons in these soils. This may be largely due to lack of good pedality in the subsurface horizons due to high gravel content and high free iron content. However, similar was the observation by Krishnamurthy (1993) in the distribution of clay and fine clay testified to the movement of the clay in these soils. Further in argillic horizons, the ratio of fine clay to total clay is greater than overlying horizons as is its character (Soil Survey Staff, 1975).

Clay accumulation was more prominent in Budagumpa. Timmapura, Sandur midland, Shivapur Kulageri and Jamakhandi pedons. However observations on texture of Devapur pedon revealed that it didnot tend to be heavier with depth

indicating there by that the mechanical translocation and subsequent accumulation of clay had in fact been of very low magnitude. Similar observations were made by Bhargava *et. al.*, (1973) and Krishnamurthy (1993).

### 5.3. Classification

It has been said that classification is the mirror which reflects the present state of knowledge. Classification of red soils of India was initiated by Rayachoudhary (1941, 1963). Govindarajan and Dutta Biswas (1968) classified red loamy soils as Paleustalfs, Rhodustalfs and Haplustalfs, The red soils of Karnataka are traditionally classified as red sandy and some are grouped under mixed red and black soils (Perur and Mithyantha, 1985). According to this classification most of the soils are grouped within mixed red and black soils. Parvatappa (1964) classified the red soils of Mysore as red loam and red soils with  $\text{CaCO}_3$  concretion. He classified these soils under Ultisols. Krishnamurthy (1993) by his investigations on red soil of North Karnataka grouped these soils under Alfisols and Inceptisols. Rudramurthy (1994) who studied associated red and black soils of North Karnataka. Grouped red soils under Alfisols and Inceptisols. Ochric epipedon is observed in all the pedons under study. Owing to the clay accumulation in B horizons, argillic horizon is present in majority of the pedons, so all these pedons are put under Alfisols except Sandur upland and midland pedons which failed to fulfill the requirements of Alfisols, hence they were put under Inceptisols and at suborder level these two pedons

were put under tropepts because of isomesic regime. The climate of all other sites is characterised by a distinct dry season and ustic moisture regime. Therefore, they are put under Ustalfs at suborder level.

Devapur Ballary, Shivapur, Devapur pedons do not have natric, oxic, cambic, petrocalcic, plinthite and duripan, Therefore they key out as haplustalfs.

Budagumpa, Timmapura, Kulageri and Kushtagipedons are grouped under Rhodustalfs at great group level owing to argillic horizons have of 2.5 YR. a colour value of moist of three or less and a colour value of dry or less and a colour value dry more than one unit higher than the moist value. Further they are classified as Typic Rhodustalfs of sub group level. Whereas Jamakhandi pedon which has a petrocalcic horizon which has its upper surface boundary within 150 cm of the mineral soil surface and thus it qualify to be grouped under Paleustalfs, (Anonymous, 1982). Ballary, Shivapur, and Devapur, pedons are grouped under Typic Haplustalfs at subgroup level.

Sandur upland and midland pedons are grouped under Ustropepts at great group level and at sub group level these are classified under Typic Ustropepts, and Jamakhandi pedon under Typic Paleustalfs.

Summary of classification for the pedons studied, is given below.

Pedons	Order	Suborder	Greatgroup	Subgroup
Ballary	Alfisols	Ustalfs	Haplustalfs	<i>Typic Haplustalfs.</i>
Budagumpa	Alfisols	Ustalfs	Rhodustalfs	<i>Typic Rhodustalfs.</i>
Timmapura	Alfisols	Ustalfs	Rhodustalfs	<i>Typic Rhodustalfs.</i>
Sandur upland	Inceptisol	Tropepts	Ustropepts	<i>Typic Ustropepts</i>
Sandur midland	Inceptisol	Tropepts	Ustropepts	<i>Typic Ustropepts.</i>
Shivapur	Alfisols	Ustalfs	Haplustalfs	<i>Typic Haplustalfs</i>
Devapur	Alfisols	Ustalfs	Haplustalfs	<i>Typic Haplustalfs</i>
Kulageri cross	Alfisols	Ustalfs	Rhodustalfs	<i>Typic Rhodustalfs</i>
Kushtagi	Alfisols	Ustalfs	Rhodustalfs	<i>Typic Rhodustalfs</i>
Jamakhandi	Alfisols	Ustalfs	Paleustalfs	<i>Typic Paleustalfs</i>

**CHAPTER - VI**

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**SUMMARY**

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## VI. SUMMARY

Ten red soil pedons from different locations of northern dry zone (agroclimatic zone-3) of Karnataka were chosen for the study of their morphological, physical and chemical properties with objectives to understand their genesis and to classify them as per U.S. Soil Taxonomy. Among the ten pedons seven were from granitic area, two from schist and one from sandstone area.

The physiography varied from pedon to pedon. The physiography of Ballary, Budagumpa Kushtagi, Shivapur and Devapur pedons is characterised by gently undulating to rolling topography on granitic terrain. Sandur pedons are associated with rolling topography schistose landscape. Where as in Timmapura, pedon physiography ranges from undulating to rolling midland. Jamakhandi pedon is located within a broad alluvial plain with sediments derived from sandstone and quartzite.

The climate of the zone ranges from semiarid to arid type. The vegetation is tropical thorn forest in majority of the pedons except Kulageri and Jamakhandi pedons which are characterised by dry deciduous type of vegetation.

Both Budagumpa pedon derived from granite gneiss and Kulgeri pedon from sandstone, exhibited red to dark reddish brown colour with hue of 2.5 YR throughout the solum. The redder hue of Kulageri pedon was related to the ferruginous nature of sandstone. Sandur upland and midland pedons

exhibited reddish brown colour throughout their depth yellower hue (5 YR) was dominant in these two pedons. In Ballary, Timmapura and Kushtagi pedons the hue changed from 5 YR at the surface, 2.5 YR in argillic horizon. However, a uniform hue of 5 YR was noticed in Jamakhandi, Shivapur and Devapur pedons.

The structure of Ballary pedon ranged from weak, fine, subangular blocky to massive. In Timmapura, Budagumpa, Devapur, Kushtagi, Kulageri and Jamakhandi pedons, structure was moderately to weakly developed and it ranged from moderate, fine, subangular blocky to weak, medium, subangular blocky. In Sandur upland and midland pedons structure was moderately developed and it varied from moderate, fine, subangular blocky to moderate, medium, subangular blocky, and in Shivapur pedon structure was moderately developed at the surface horizons and massive structure was noticed in lowermost horizon.

Clay skins on ped faces were not prominent due to weak structure, abundance of coarse fragments and high iron oxide content.

The consistency of soils ranged from friable to very friable when moist and hard to very hard when dry. They were slightly sticky to sticky and nonplastic to plastic when wet. Among the different pedons Timmapura and Kushtagi pedons were characterised by abundance of coarse fragments. General content was minimum in Shivapur pedon followed by Sandur midland pedon.

All the pedons were characterised by high gravel content except Shivapur, Sandur midland and Jamakhandi pedons.

The gravel content was especially high in Timmapura (colluvium) and Kushtagi pedons on granitic land scape, Kulageri on sandstone and Sandur upland (schist). Sand size particles were dominant in all the pedons comprising more than 50 per cent of the mineral matter. Of the different fractions very coarse sand content predominated over others in all the pedons from granite gneissic area, compared to schist derived soils where fine and very fine sand fractions contributed to the bulk of the total sand. However in sandstone derived soil (Kulgeri pedon) both very coarse sand and fine and very fine sand fractions were about the same proportion and predominated over other fractions of sand.

The clay and fine clay contents were maximum in Bt or Bw horizons in all the pedons. The clay content of granite gneiss pedons ranged from 7.2 to 18.8 percent and fine clay from 2.2 to 6.2 per cent at the surface. The corresponding values in the Bt horizons ranged from 12.5 to 32.2 per cent. Both clay and fine clay distribution with depth was similar in all the pedons.

In general the texture was sandy loam at the surface and sandy clay loam in Bt horizons of are the pedons. The exception being Sandur pedons which were sandy clay loam throughout and Shivapur and Devapur with sand to loamy sand at surface and sandy loam at Bt horizon.

The bulk density was relatively more in all the pedons and decreased in 'Bt' horizons due to higher clay

content. Available water holding capacity was relatively more in Sandur soils derived from schist than others. Sandur midland exhibited highest waterholding capacity of 21.0 per cent at 33 kPa and 10.1 per cent at 1500 kPa. Among the soils derived from granitic parent material, Kushtagi, Jamakhandi and Kulageri pedons exhibited higher waterholding capacity.

Surface area also was highest in Sandur pedons compared to others ranging from 82.4 to 114.2  $\text{m}^2 \text{g}^{-1}$ . In other pedons surface area ranged from 52.4 to 98.6  $\text{m}^2 \text{g}^{-1}$ .

Soil reaction was measured both in soil-water suspension and 1N. KCl solution. The  $\text{p}^{\text{H}}$  of soils ranged from mildly acidic to mildly alkaline and increased with depth in all the pedons. The electrical conductivity was low. Organic carbon content was more in Sandur pedons compared to other. Organic carbon content decreased with depth in all the pedons.

Dithionite extractable iron ( $\text{Fe}_{\text{d}}$ ) and oxalate extractable iron ( $\text{Fe}_{\text{o}}$ ) were highest in 'Bt' horizons due to increase in clay content. Among the different pedons both  $\text{Fe}_{\text{d}}$  and  $\text{Fe}_{\text{o}}$  content was highest in Sandur pedons.  $\text{Fe}_{\text{o}}$  content in Kulgeri pedon was distinctly greater than other pedons.

Among the different exchangeable bases calcium was the predominant cation followed by magnesium. Exchangeable sodium and potassium were low.  $\text{BaCl}_2$  TEA decreased with depth and closely followed the trend of organic carbon, in all the pedons.

Cation exchange capacity of soils followed the trend of distribution of clay and was maximum in argillic horizons of all the pedons. Among the granite gneiss pedon the CEC ranged from 4.8 c mol (p+) kg<sup>-1</sup> to 17.2 c mol (p+) kg<sup>-1</sup> in Bt horizons.

Soil-physiography relationships and parent material have played a prime role in the pedogenesis of different soils studied, with climate as a secondary factor. The soils were shallow to moderately deep in pedons situated in uplands and deep to very deep in midland situations. Erosion and redistribution of weathered materials have been responsible for the observed properties. The content of finer constituents especially the clay particles is comparatively greater in the pedons situated in lower elements of the land scape. Parent material was found to influence physical, chemical and mineralogical properties of the soils and had a key role in the genesis of these soils. Soils derived from granitic parentage have low silt content and high sand content compared to soils derived from schist which have lesser sand content and comparatively higher silt content.

Illuviation of clay has been an important pedogenic process in these soils as judged by clay and fine clay distribution, although morphologic expression is not prominent.

The classification of these soils according to U.S. soil Taxonomy revealed that all the pedons except Sandur upland and midland, belong to Alfisols order since all have argillic

horizon. Sandur upland and midland belong to order Inceptisol. and at sub order level there two pedons are put under Tropepts and remaining pedons are put under Ustalfs as they tend to be very dry for considerable periods in a year. A great group level Ballary, Shivapur and Devapur pedons qualify for Haplustalfs, Budagumpa, Kudalagi, Kushtagi pedons are grouped under Rhodustalfs and Jamakhandi pedon under Paleustalfs. Where as Sandur upland and midland pedons key out as Ustropepts.

At sub group level they are grouped as below.

Pedons	Subgroup
Ballary	<i>Typic Haplustalfs</i>
Budagumpa	<i>Typic RhOdustalfs</i>
Timmapura	<i>Typic Rhodustalfs</i>
Sandur upland	<i>Typic Ustropepts</i>
Sandur midland	<i>Typic Ustropepts</i>
Shivapur	<i>Typic Haplustalfs</i>
Devapur	<i>Typic Haplustalfs</i>
Kulageri	<i>Typic Rhodustalfs</i>
Kushtagi	<i>Typic Rhodustalfs</i>
Jamakhandi	<i>Typic Paleustalfs</i>

**CHAPTER - VII**

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\*Originals are not seen.

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# APPENDICES

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Venkatagiri surface sample

Appendix 1. Morphology, Particle size distribution and physico-chemical properties

1. General description		4. Physico-chemical properties	
Location	10 kms from Gangavati, on Gangavati-Koppal road Cultivated	pH (1;2.5::Soil:Water)	7.71
Land use		pH (1:2.5::Soil:1 N KCl)	6.91
2. Morphological features		EC	0.15 dSm <sup>-1</sup>
Colour	2.5 VR 4/5(d), 2.5VR 3/4(m)	Organic Carbon	0.27%
Texture	ls	Fed	1.11%
Structure	2.m.sbk	Feo	0.43%
Consistency	s(d). fr(m)	CEC	13.6 c mol (p+) kg <sup>-1</sup>
Plasticity	Ps	BaCl <sub>2</sub> -TEA extractable acidity	3.0 c mol (p+) kg <sup>-1</sup>
Stickiness	ss	33 kPa	5.26%
3. Particle size distribution		1500 kPa	2.18%
Coarse fragments	12%	Exch. Ca	9.40 c mol (p+) kg <sup>-1</sup>
Very coarse sand	16.0%	Exch. Mg	1.40 c mol (p+) kg <sup>-1</sup>
Coarse sand	16.6%	Exch. Na	0.58 c mol (p+) kg <sup>-1</sup>
Medium sand	16.2%	Exch. K	0.21 c mol (p+) kg <sup>-1</sup>
Fine sand	20.5%		
Very fine sand <sup>a</sup>	15.9%		
Total sand	85.2%		
Silt	10.2%		
Clay	4.6%		
Very fine clay	1.8%		

Indragu Tanda surface sample

Appendix 2. Morphology, Particle size distribution and physico-chemical properties

<b>1. General description</b>		<b>4. Physico-chemical properties</b>	
Location	24 kms from Gangavati, on Gangavati-Koppal Cultivated	pH (1:2.5::Soil:Water)	5.99
Land use		pH (1:2.5::Soil:1 N KCl)	4.72
<b>2. Morphological features</b>		EC	0.04 dSm <sup>-1</sup>
Colour	2.5 YR 4/5(d), 2.5YR 3/4(m)	Organic Carbon	0.36%
Texture	sl	Fed	1.10%
Structure	2.m.sbk	Feo	0.40%
Consistency	sh(d). fr(m)	CEC	8.80 c mol (p+) kg <sup>-1</sup>
Plasticity	Po	BaCl <sub>2</sub> -TEA extractable acidity	3.20 c mol (p+) kg <sup>-1</sup>
Stickiness	ss	33 kPa	14.46%
<b>3. Particle size distribution</b>		1500 kPa	6.10%
Coarse fragments	2%	Exch. Ca	5.40 c mol (p+) kg <sup>-1</sup>
Very coarse sand	22.0%	Exch. Mg	1.00 c mol (p+) kg <sup>-1</sup>
Coarse sand	10.5%	Exch. Na	0.42 c mol (p+) kg <sup>-1</sup>
Medium sand	11.2%	Exch. K	0.15 c mol (p+) kg <sup>-1</sup>
Fine sand	11.5%		
Very fine sand	15.9%		
Total sand	71.1%		
Silt	10.5%		
Clay	18.4%		
Very fine clay	8.9%		

Gugadal surface sample

Appendix 3. Morphology, Particle size distribution and physico-chemical properties

1. General description	4. Physico-chemical properties
Location	pH (1:2.5::Soil:Water) 7.87
	pH (1:2.5::Soil:1 N KCl) 6.24
Land use	EC 0.23 dSm <sup>-1</sup>
2. Morphological features	Organic Carbon 0.39%
Colour	Fed 1.29%
Texture	Feo 0.52%
Structure	CEC 9.6 c mol (p+) kg <sup>-1</sup>
Consistency	BaCl <sub>2</sub> -TEA extractable 3.20 c mol (p+) kg <sup>-1</sup>
Plasticity	acidity
Stickiness	33 kPa
3. Particle size distribution	1500 kPa
Coarse fragments	Exch. Ca 5.60 c mol (p+) kg <sup>-1</sup>
Very coarse sand	Exch. Mg 1.60 c mol (p+) kg <sup>-1</sup>
Coarse sand	Exch. Na 0.32 c mol (p+) kg <sup>-1</sup>
Medium sand	Exch. K 0.14 c mol (p+) kg <sup>-1</sup>
Fine sand	
Very fine sand	
Total sand	
Silt	
Clay	
Very fine clay	

Kirloskar factory (Gingera) surface sample

Appendix 4. Morphology, Particle size distribution and physico-chemical properties

1. General description		4. Physico-chemical properties	
Location	Near Kirlockar factory	pH (1:2.5::Soil:Water)	6.6
Land use	on Gingera-Hospeth road Cultivated	pH (1:2.5::Soil:1 N KCl)	5.98
2. Morphological features		EC	0.23 dSm <sup>-1</sup>
Colour	2.5 YR 5/6(d), 2.5YR 4/6(m)	Organic Carbon	0.36%
Texture	sl	Fed	1.72
Structure	2.m.sbk	Feo	0.70%
Consistency	sh(d). fr(m)	CEC	13.74 c mol (p+) kg <sup>-1</sup>
Plasticity	p	BaCl <sub>2</sub> -TEA extractable	3.20 c mol (p+) kg <sup>-1</sup>
Stickiness	s	acidity	9.10%
3. Particle size distribution		33 kPa	4.20%
Coarse fragments	1%	1500 kPa	8.00 c mol (p+) kg <sup>-1</sup>
Very coarse sand	18.2%	Exch. Ca	1.80 c mol (p+) kg <sup>-1</sup>
Coarse sand	10.8%	Exch. Mg	0.50 c mol (p+) kg <sup>-1</sup>
Medium sand	11.5%	Exch. Na	0.24 c mol (p+) kg <sup>-1</sup>
Fine sand	18.9%	Exch. K	
Very fine sand	17.7%		
Total sand	77.1%		
Silt	10.4%		
Clay	12.5%		
Very fine clay	5.6%		

Bellary surface sample

Appendix 5. Morphology, Particle size distribution and physico-chemical properties

1. General description		4. Physico-chemical properties	
Location	42nd milestone from Bellary onPH (1;2.5::Soil:Water)		6.6
	Bellary-Gangavati road	pH (1:2.5::Soil:1 N KCl)	5.46
Land use	Cultivated	EC	0.08 dSm <sup>-1</sup>
2. Morphological features		Organic Carbon	0.51%
Colour	7 YR 4/4(d), 7 YR 4/3 (m)	Fed	2.45%
Texture	sl	Feo	1.03%
Structure	2.m.sbk	CEC	16.20 c mol (p+) kg <sup>-1</sup>
Consistency	sh(d). fr(m)	BaCl <sub>2</sub> -TEA extractable	3.40 c mol (p+) kg <sup>-1</sup>
Plasticity	P	acidity	
Stickiness	S	33 kPa	11.92%
3. Particle size distribution		1500 kPa	4.10%
Coarse fragments	46%	Exch. Ca	14.00 c mol (p+) kg <sup>-1</sup>
Very coarse sand	16.4%	Exch. Mg	1.60 c mol (p+) kg <sup>-1</sup>
Coarse sand	10.7%	Exch. Na	0.42 c mol (p+) kg <sup>-1</sup>
Medium sand	11.4%	Exch. K	0.17 c mol (p+) kg <sup>-1</sup>
Fine sand	15.0%		
Very fine sand	8.6%		
Total sand	62.1%		
Silt	18.1%		
Clay	18.8%		
Very fine clay	6.6%		

Kudathini surface sample

Appendix 6. Morphology, Particle size distribution and physico-chemical properties

1. General description	4. Physico-chemical properties
Location	pH (1:2.5::Soil:Water) 7.56
	pH (1:2.5::Soil:1 N KCl) 6.72
Land use	EC 0.15 dSm <sup>-1</sup>
2. Morphological features	Organic Carbon 0.45%
Colour	2.5 YR 5/6(d), 2.5 YR 4/6 (m) Fed 3.28%
Texture	s 1.64%
Structure	2.f.sbk 8.00 c mol (p+) kg <sup>-1</sup>
Consistency	sh(d). fr(m) 3.40 c mol (p+) kg <sup>-1</sup>
Plasticity	p acidity
Stickiness	s 33 kPa 5.72%
3. Particle size distribution	1500 kPa 1.20%
Coarse fragments	Exch. Ca 6.00 c mol (p+) kg <sup>-1</sup>
Very coarse sand	Exch. Mg 1.20 c mol (p+) kg <sup>-1</sup>
Coarse sand	Exch. Na 0.56 c mol (p+) kg <sup>-1</sup>
Medium sand	Exch. K 0.22 c mol (p+) kg <sup>-1</sup>
Fine sand	
Very fine sand	
Total sand	
Silt	
Clay	
Very fine clay	

Taranagar surface sample

Appendix 7. Morphology, Particle size distribution and physico-chemical properties

1. General description		4. Physico-chemical properties	
Location	12 kms from Sandur	pH (1:2.5::Soil:Water)	7.97
Land use	Cultivated	pH (1:2.5::Soil:1 N KCl)	6.9
2. Morphological features		EC	0.17 dSm <sup>-1</sup>
Colour	2.5 YR 4/6(d), 2.5 YR 4/6 (m)	Organic Carbon	0.21%
Texture	sl	Feo	1.19%
Structure	2.f.sbk	CEC	0.43%
Consistency	sh(d). fr(m)		23.78 c mol (p+) kg <sup>-1</sup>
Plasticity	p	BaCl <sub>2</sub> -TEA extractable acidity	3.00 c mol (p+) kg <sup>-1</sup>
Stickiness	s		10.06%
3. Particle size distribution			4.82%
Coarse fragments	28%		18.00 c mol (p+) kg <sup>-1</sup>
Very coarse sand	19.5%	Exch. Ca	2.20 c mol (p+) kg <sup>-1</sup>
Coarse sand	9.5%	Exch. Mg	0.45 c mol (p+) kg <sup>-1</sup>
Medium sand	10.5%	Exch. Na	0.17 c mol (p+) kg <sup>-1</sup>
Fine sand	17.9%	Exch. K	
Very fine sand	16.7%		
Total sand	73.4%		
Silt	12.2%		
Clay	14.4%		
Very fine clay	5.6%		

Somalapur surface sample

Appendix 8. Morphology, Particle size distribution and physico-chemical properties

1. General description		4. Physico-chemical properties
Location	21 kms from Kudalagi on Sandur-Kudalagi road	pH (1:2.5::Soil:Water) 6.78
Land use	Cultivated	pH (1:2.5::Soil:1 N KCl) 5.5
2. Morphological features		EC 0.11 dSm <sup>-1</sup>
Colour	2.5 YR 4/6(d), 2.5 YR 3/6 (m)	Organic Carbon 0.45%
Texture	sl	2.51%
Structure	2.m.sbk	1.17%
Consistency	s(d). fr(m)	12.40 c mol (p+) kg <sup>-1</sup>
Plasticity	p	3.20 c mol (p+) kg <sup>-1</sup>
Stickiness	s	acidity
3. Particle size distribution		33 kPa 9.10%
Coarse fragments	83%	1500 kPa 5.60%
Very coarse sand	19.5%	Exch. Ca 10.00 c mol (p+) kg <sup>-1</sup>
Coarse sand	11.1%	Exch. Mg 2.00 c mol (p+) kg <sup>-1</sup>
Medium sand	8.7%	Exch. Na 0.20 c mol (p+) kg <sup>-1</sup>
Fine sand	12.9%	Exch. K 0.12 c mol (p+) kg <sup>-1</sup>
Very fine sand	19.0%	
Total sand	71.2%	
Silt	14.4%	
Clay	14.4%	
Very fine clay	4.5%	

Bandri surface sample

Appendix 9. Morphology, Particle size distribution and physico-chemical properties

1. General description		4. Physico-chemical properties	
Location	15 kms from Kudalagji	pH (1;2.5::Soil:Water)	6.54
Land use	Cultivated	pH (1:2.5::Soil:1 N KCl)	5.45
2. Morphological features		EC	0.26 dSm <sup>-1</sup>
Colour	7.5 YR 5/5(d), 7.5 YR 4/5 (m)	Organic Carbon	0.57%
Texture	s		1.26%
Structure	2.m.sbk	Feo	nd
Consistency	sh(d). fr(m)	CEC	6.00 c mol (p+) kg <sup>-1</sup>
Plasticity	Po	BaCl <sub>2</sub> -TEA extractable	4.20 c mol (p+) kg <sup>-1</sup>
Stickiness	SS	acidity	
3. Particle size distribution		33 kPa	5.24%
Coarse fragments	29%	1500 kPa	2.32%
Very coarse sand	16.2%	Exch. Ca	4.40 c mol (p+) kg <sup>-1</sup>
Coarse sand	18.7%	Exch. Mg	1.20 c mol (p+) kg <sup>-1</sup>
Medium sand	24.1%	Exch. Na	0.32 c mol (p+) kg <sup>-1</sup>
Fine sand	16.2%	Exch. K	0.14 c mol (p+) kg <sup>-1</sup>
Very fine sand	14.0%		
Total sand	89.2%		
Silt	14.2%		
Clay	6.6%		
Very fine clay	2.5%		

Kudalagi surface sample

Appendix 10. Morphology, Particle size distribution and physico-chemical properties

1. General description	4. Physico-chemical properties
Location	Near 8th milestone from Kudalagi pH (1:2.5::Soil:Water) 6.75
Land use	on Kudalagi-Sandur road pH (1:2.5::Soil:1 N KCl) 5.3
2. Morphological features	Cultivated EC 0.19 dSm <sup>-1</sup>
Colour	5 YR 5/6(d), 5 YR 4/6 (m) Organic Carbon 0.12%
Texture	sl Fed 2.19%
Structure	2.m.sbk Feo 1.00%
Consistency	sh(d). fr(m) CEC 7.40 c mol (p+) kg <sup>-1</sup>
Plasticity	Ps BaCl <sub>2</sub> -TGA extractable 1.80 c mol (p+) kg <sup>-1</sup>
Stickiness	SS acidity 9.21%
3. Particle size distribution	33 kPa 5.61%
Coarse fragments	1500 kPa
Very coarse sand	Exch. Ca 5.80 c mol (p+) kg <sup>-1</sup>
Coarse sand	Exch. Mg 1.20 c mol (p+) kg <sup>-1</sup>
Medium sand	Exch. Na 0.38 c mol (p+) kg <sup>-1</sup>
Fine sand	Exch. K 0.15 c mol (p+) kg <sup>-1</sup>
Very fine sand	
Total sand	
Silt	
Clay	
Very fine clay	

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ಗಾ.ಕೃ.ವಿ.ಕೆ, ಬೆಂಗಳೂರು-65

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