ORGANIC CARBON MAPPING OF AGRO-ECOLOGICAL ZONES OF MARATHWADA REGION OF MAHARASHTRA STATE

By

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M.Sc. (Agri.)

THESIS

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Department of Soil Science and Agricultural Chemistry,

Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani 431 402 (M.S.)

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2013

CANDIDATE'S DECLARATION

I hereby declare that this dissertation or part thereof has not been previously submitted by me to any other University or institution for a degree or diploma.

Place: PARBHANI

Date :/23 / 12 / 2013

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CERTIFICATE - I

This is to certify that the dissertation entitled **"ORGANIC CARBON MAPPING OF AGRO ECOLOGICAL ZONES OF MARATHWADA REGION OF MAHARASHTRA STATE"** submitted by **MR. MALODE KAILASH RAMESHRAO** to the Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani, in partial fulfillment of the requirement of the degree of **DOCTOR OF PHILOSOPHY** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** is a record of original bonafide research work prosecuted by him under my guidance and supervision. The dissertation, in my opinion is of sufficiently high standard to warrant it's presentation for the award of the said degree.

I also certify that the dissertation or part thereof has not been previously submitted by him for any degree, diploma or distinction to any other University/institution. The assistance and help rendered during the course of investigation and sources of literature have been duly acknowledged.

Place: PARBHANI

Date: 20/12/2013

(V. D. PATIL)
Research Guide

CERTIFICATE - II

This is to certify that the dissertation entitled **"ORGANIC CARBON MAPPING OF AGRO ECOLOGICAL ZONES OF MARATHWADA REGION OF MAHARASHTRA STATE"** submitted by **MR. MALODE KAILASH RAMESHRAO** to the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (M.S.) in partial fulfillment of the requirement for the degree of **DOCTOR OF PHILOSOPHY** in the subject of **SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**has been approved by the student's advisory committee after viva-voce examination in collaboration with the external examiner.

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Malode Kailash Rameshrao

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LIST OF ABBREVIATIONS

AD	:	Arid Dry
AWC	:	Available Water Content
BCS	:	Black Cotton Soils
BD	:	Bulk Density
CC	:	Coarse Clay
COLE	:	Coefficient of Linear Extensibility
CO_2	:	Carbon-di-oxide
D	:	Dry
ECe	:	Electrical Conductivity of the saturation extract
ECP	:	Exchangeable Calcium Percentage
EMP	:	Exchangeable Magnesium Percentage
ESP	:	Exchangeable Sodium Percentage
FC	:	Fine Clay
HT	:	Humid Tropic
LE	:	Linear Extensibility
LGP	:	Length of Growing Period
M	:	Moist
MAR	:	Mean Annual Rainfall
MAT	:	Mean Annual Temperature
Mt	:	Miters
MSL	:	Mean Sea Level
μm	:	Micrometer.
%	:	Percent
/	:	Per
ha	:	Hectare
Kg	:	Kilogram
g	:	Gram
dSm^{-1}	:	Desisyman per meter
mg	:	Milligram
Lit	:	Liter
ppm	:	Parts Per million

N	:	Nitrogen
P	:	Phosphorus
K	:	Potassium
Ca	:	Calcium
$CaCO_3$	:	Calcium Carbonate
Zn	:	Zinc
Fe	:	Iron
Mn	:	Manganese
Cu	:	Copper
CC	:	Cubic Centimeter.
NPC	:	Non Pedogenic Carbonate
^0C	:	Degree Centigrate
PAWC	:	Plant Available Water Content
PC	:	Pedogenic Carbonate
PET	:	Potential Evapo transpiration
%	:	Percentage
QEV	:	Quasi-equilibrium value
SAD	:	Semi-Arid Dry
SAM	:	Semi-Arid Moist
SAR	:	Sodium Adsorption Ratio
SHC	:	Saturated Hydraulic conductivity
SHD	:	Sub-Humid Dry
SHM	:	Sub-Humid Moist
SIC	:	Soil Inorganic Carbon
SMBC		Soil Microbial Biomass carbon
SIC		Soil Inorganic Carbon
Sm/K	:	Interstratified Smectite / kaolinite
SOC	:	Soil Organic Carbon
TC	:	Total Carbon
TEC	:	Total Electrolyte Concentration
WDC	:	Water Dispersible Clay
YR	:	Yellowish Red

INTRODUCTION

Chapter-I

INTRODUCTION

Soil is the largest pool of terrestrial organic carbon in the biosphere, storing more C than is contained in plants and the atmosphere combined (Schlesinger 1997). The abundance of organic C in the soil affects and is affected by plant production, and its role as a key control of soil fertility and agricultural production has been recognized for more than a century (Dokuchaev 1883, Hilgard 1906, Jenny 1941, Tiessen *et al.*, 1994). The patterns and controls of soil organic carbon (SOC) storage are critical for our understanding of the biosphere, given the importance of SOC for ecosystem processes and the feedback of this pool to atmospheric composition and the rate of climate change (Raich and Potter 1995, Trumbore *et al.*, 1996, Woodwell *et al.*, 1998). Our capacity to predict and ameliorate the consequences of climate and land cover change depends, in part, on a clear description of SOC distributions and the controls of SOC inputs and outputs.

Many important global and regional SOC budgets are available (e.g., Schlesinger 1977, Post *et al.*, 1982, Eswaran *et al.*, 1993, Kern 1994, Batjes 1996). One aspect of the organic carbon pool that remains poorly understood is its vertical distribution in the soil and accompanying relationships with climate and vegetation. In addition to climate, soil texture plays an important role, with increasing clay content decreasing C outputs through its stabilizing effect on SOC (e.g., Paul, 1984). As expected from these controls, regional patterns of SOC are positively associated with mean annual precipitation and clay content, and are negatively correlated with mean annual temperature in a diverse array of soils and vegetation types.

We hypothesize that vegetation is a major determinant of the vertical distribution of SOC. Although climate and soil texture are the primary regional controls of the total amount of SOC, their influence on the vertical distribution of SOC may be eclipsed by the effects of plant allocation. Plant production and decompositions determine C inputs to the soil profile, and plant allocation above and below ground and between shallow and deep roots may leave distinct imprints on the relative distribution of soil carbon with depth. An analysis by Jackson *et al.* (1996) examined above and below ground allocation patterns and vertical root distributions for terrestrial biomes and plant functional types, showing differences among grass-, shrub-, and tree-dominated systems. In arid systems, the relatively deep root distributions of shrubs may lead to soil C profiles that are deeper than those in arid grasslands. Soil C surveys usually consider a fixed soil depth, typically 1 m. Global surveys based on vegetation units (Post *et al.*, 1982) and soil taxonomic units (Eswaran *et al.*, 1993; Batjes 1996) indicate that the soil stores ;1500–1600 Pg of C in this first meter. Based on the FAO soil classification system, Batjes (1996) reported a 60% increase in the global SOC budget when the second meter of soil was included.

Soil is vital natural resource on whose proper use depend the life supporting system of a country and the socio-economic development of its people. Soils provide food, fodder and fuel for meeting the basic needs of human and animal. With the growth in human and animal population, demand for more food production is increasing. However, the capacity of the soil to produce is limited. Production limits are set by intrinsic characteristics, Agro-ecological setting, use and management of soil. This demands systematic appraisal of our soil resources with respect to their extent, distribution, characteristic behavior and use potential, which is very important for developing an effective land use system for augmenting agriculture production on sustainable basis. Soil Organic Matter (SOM) is the most often reported attribute and is chosen as the most important character of soil quality and agricultural sustainability. The soil organic matter is not only source of carbon but also a sink for carbon sequestration. Cultivation and tillage can reduce SOC content and lead to soil deterioration. Tillage practices have a major effect on distribution of C and N, and the rates of organic matter decomposition. Proper adoption of crop rotation can increase and maintain the quantity and quality of soil organic matter, and improve soil chemical and physical properties. Soil can be a source and sink for atmospheric CO_2 depending upon the land use and management of soil and vegetation (Lal, 2005). The depletion of SOC pool is exacerbated when the rate of C returned to the soil is less than the rate of decomposition. Surface soil rich in SOC is disturbed by ploughing and other pedoturbations (Lal, 2005). The conversion of native ecosystems (e.g. forests, grasslands and wetlands) to agricultural uses, and the continuous harvesting of plant materials, has led to significant losses of plant biomass and carbon there by increasing the CO_2 level in the atmosphere.

In Maharashtra, most of the soils have developed over basaltic parent material and are heavier in texture. These soils are classified as Vertisols and associated soils (very deep to very shallow) as per USDA soil classification system. A survey in Maharashtra showed that black soil having depth of ~ 60 cm constituting 45 percent of an area in 1910 was reduced to 18 percent after 50 years. The remaining 27 per cent almost got turn to shallow soils category (Abrol, 1991). It was also reported by Bhaskar *et al.* (1987) the shallow, medium deep and deep soils cover 36.2, 38.1 and 25.7 per cent area, respectively in the state. Thus shallow soil covers larger area as compared to deep soils. The organic carbon varied from 0.23 to 0.81 per cent, and it was higher in surface soils as compared to subsurface soils (Patil 2013, Bharambe 1999, Sharma and Bali 2000). The process of SOC sequestration involves humification of C returned to soil as biomass. In addition to C, other elements essential to the process of humification are N, P, S Ca and Mg etc. addition nutrients are required because the ratio of C:N, C:P, C:S etc, are much winder in the biomass than in the humus.

The importance of soil survey and mapping for preparing an inventory of a region, the soil properties are used for evaluation of soil for different crops. The value of soil resource inventory for increased food production and conservation of natural resources has been receiving significant importance not only for soil resource data base generated but also its quality (Eswaran and Gathrie 1982). As there is chaos around us regarding the decreasing status of organic carbon content of cultivated soils of Maharashtra in general as Marathwada in particular. Soil organic carbon mapping is necessary in recent years. Even though the organic carbon status of the area is not yet mapped. Therefore attempt has been made to map the data of SOC generated from the present research project. This will act as a ready reckoner for the researchers to plan their research studies, extension workers to guide the farmers for optimum fertilizer application and farmers to get an idea of their farm regarding soil health status , so that futuristic appropriate corrective measures can be taken up to get and sustain the optimum crop productivity.

The soil organic matter is highly dynamic in natural, both qualitatively and qualitatively, the usefulness of organic matter in maintaining soil productivity lies in its dynamic nature. Freshly added organic matter subject to the process of decomposition under the influence of microorganisms. Subsequently it re synthesis to newer organic substance of complex nature leading to the formation of human substance. During this process of decomposition and re synthesis into a humus substance, various plants nutrients are released into soil environment to be utilized by growing plants. However, the subtropical climate of Marathwada region of Maharashtra state poses a problem of organic matter deposition/accumulation in a soil profile. Because of high temperature the soil organic matter decomposition rate is high and hence its accumulation is low. In addition to this there are many other factors that influence the organic carbon status of soils of Marathwada. Multiple cropping systems coupled with clean cultivation over the years reduced the organic carbon content of these soils. In recent reports (Patil, 2013 a) it was observed that organic carbon status of soils of Marathwada was decreased to a greater extent. For an instance, in Jalna district of Marathwada it was reported that organic carbon content of soil was reduced from 0.6 per cent to 0.3 per cent in last 40 years. This is an alarming situation for the agriculture and researchers of the region.

Cropping pattern, decisions and land use have always been part of the evolution of human society. The function of the land use planning is to guide such a way that the resources of the environment were put to the most beneficial use for man, this planning based on an understanding both of the natural environment and of the kind of land use envisaged. It also involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative form of land use. Every plant species need specific soil-site conditions for its optimum growth and yield, imperative to use the finite soil resource according to its capability or suitability for particular land use. This can be achieved only by Agro-ecologically zone and critically evaluating the soil-site conditions vis-à-vis specific climatic characteristics of different crops Soil –site suitability is the fitness of given type of land for a defined use. The processes of the land suitability classification are the appraisal and grouping of specific Agro-ecologically zone of land in term of their suitability and to estimate the potential of a particular soil for alternative uses. The basic feature is the comparison of the requirements of land use with the resources offered by the land.

The FAO framework on Land Evaluation (FAO 1976) suggests a crop specific suitability system. However no attempt has been made to determining soil-site suitability evaluation of the crop commonly cultivated in the Agro-ecologically zone of Marathwada region such as soybean, pigeon pea and cotton. Therefore in the present investigation an attempts has been made on the basis of literature available and on specific crop requirement and propose the soil site suitability keeping into account the local conditions.

The data base of organic carbon status of region, which is life line of agricultural production, is not available till to date. Hence, the study "Organic carbon mapping of Agro-ecological zones of Marathwada" was undertaken to determine the organic carbon status in a range of Marathwada soils under divers climatic and cropping systems with following objectives.

Objectives

- To study the organic carbon content in varied soil series and surface soils of Agro-ecological regions of Marathwada.
- To evaluate the physical and chemical properties and dynamics of nutrient status of soils of Marathwada region.
- To find out relationship between C:N, C:P, and C:S ratio and soil properties under varied agro ecological regions of Marathwada.
- To prepare maps of soil organic carbon status.
- To study the cropping pattern and land use of Agro-ecological region of Marathwada.

REVIEW OF LITERATURE

Chapter-II

REVIEW OF LITERATURE

Balanced chemical fertilizers with regular and prolonged use of manures and crop residues are likely to bring some changes in physical, chemical and biological properties of soils. No development plan can be successful unless it is based on reliable knowledge on the extent of different kinds of soils in relation to climate, vegetation and potential crop production. The content of soil organic matter sequestration in soil depends upon number of factors *viz.* temperature, rainfall, vegetation, topography and time. The focus of review of focus is on the research work done by different workers on organic carbon mapping and allied fields. The review was collected from Journals, periodicals, books, internet, personal communication and other literature available on this aspect as presented in following sub heads.

2.1 Characterization and classification of soils.

2.2 Soil properties.

2.2.1 Physical properties of soil.

2.2.2 Chemical properties of soil.

2.2.2.1 Macronutrient status

2.2.2.2 Micronutrient status

2.3 Soil organic carbon, inorganic carbon and total carbon status.

2.3.1 C:N, C:P and C:S ratio's and its influence on soil properties.

2.4 Effect of various factors on organic carbon and nutrient status.

2.5 Soil site suitability for different crops.

2.1 Characterization and classification of soils.

The important tasks of soil survey are description, classification site characteristics which influence crop growth and soil characteristics are briefly described as below.

Walkar *et al.* (1968) reported that landform parameter such as slope, length and direction, curvation, distance from the hill slope summit and its relative elevation influence the soil profile development. They also observed the influence the slope, length and its direction on horizon development.

Landey *et al.* (1982) reported that black soil and associated soils were found on various micro-land form unit both erosional and depositional. The depositional features are generally residual hill ranges directed means of butte, escarpment and pediments while the depositional features are visible in the piedmont plain margin gradually with the valley floor. He was also observed that the texture of black soil were usually fine and varied from clay loam, silty clay to clay. The clay content varies from 35 to 60 percent. They also observed that the bulk density was normally high in black soils and the normal range estimated with dry clod method ranged between 1.5 to 1.8 Mg m^{-3}.

Vadivelu (1983) reported that soil – site and climatic characteristics changes with geomorphic unit which is turn influence on land use pattern, They observed that hill ridges with shallow soil were mostly under forest with patches of rainfed crops. The pediments surface with shallow to deep soils were cultivated to sorghum and soybean and pearl millet, while the soils occurring on pediment plain and flood plains were very deep and cultivated to sorghum, pigeon pea, safflower under rainfed condition.

Pal and Deshpande (1987) reported that basalt rocks readially weathers to fine clay and this could be the reason for high clay and low content of sand in deep black soil.

Srivastava *et al.* (1991) studied the soils of Ujjain district of Madhya Pradesh and observed that the soils on hill and ridges were shallow, excessively drained with problem of severe erosion soils on gently slopy to undulating lands were as deep to very deep, well rained and were suitable for arable crops if irrigation was provided. Soil on gentle sloping land was very deep, moderately well drained calcareous and were under cultivation.

Morphology, physical and chemical characteristics and land use plans of basaltic trap derived soils representing different landforms in Pratapgarh region of Southern Rajasthan were studied. The soils at elevated topography were shallow to moderately shallow, clayey to loamy skeletal and yellowish brown, while at lower topography were deep to very deep, fine to fine loamy and grayish. The influence of topography had a marked influence on properties like pH, $CaCO_3$, clay content, vertic properties, cation exchange capacity and exchangeable cations upto pedon 4, thereafter they were subdued by local ephemeral. The soils were classified taxonomically upto sub-groups and land use plans for the soils associated with each landform are proposed for its better management (Sharma *et al.*, 1996).

Sharma *et al.* (1996) has classified the soils of Haldi Ghats Watershed of Rajasthan considering the morphological observations, physical and chemical characteristics of the soils. He has indicated that land form position *i.e.*, physiography has left a distinct imprint on the overall soil features which form the basis of putting the soils under different taxa. The soils formed over the side slopes were classified as coarse silty Lithic Ustorthents, those on gently sloping foot slopes as fine loamy Typic Ustochrepts, those on gently to moderately sloping plains as coarse loamy Typic Ustochrepts, those on nearly level to gently sloping alluvial plains as coarse loamy over fine loamy Typic Ustochrepts. The relative stability of landform provided the soils to acquire appreciable depth as well as opportunity for the pedogenic process to take place as evidenced by the aggregation process. The soils of the flood plains were classified as coarse loamy, Typic Ustifluvents as they were subjected to frequent additions of newer materials and removal of older ones, thereby leaving little scope for pedogenic process to manifest.

Sharma *et al.* (2001a) studied seven soil series belonging to Entisols, Inceptisols and Vertisols occurring on residual hummocks and ridges, pediment, pediment/valley, flood plain and costal plain in Rajkot district of central Kathiawar region of Gujarat state were studied. The soils differed widely in their morphological, physical and chemical characteristics. Significant variations in soil depth, drainage, colour and structure were observed in relation to toposequence. Soils occurring on upper elements of topography are shallow to moderately deep, some what excessively well drained, clay loam to clay in texture and reddish brown to dark brown in colour, whereas soils occurring on lower elements of topography are deep to very deep, moderately well drained to poorly drained, clay in texture and grayish brown to dark grayish brown in colour. Soils in general, were low in organic carbon but high in clay content, cation exchange capacity and base saturation, irrespective of their physiographic position. Calcium dominated the exchange complex. Soils occurring on lower element of topography were strongly calcareous and showed mottling.

Shamsudheen *et al.* (2005) characterized the forest soils of N karnataka for their morphological, physical and chemical proerpties. The texture and colour (hue) of soils varied from sandy loam to clay and 2.5 YR to 10 YR, respectively associated with predominantly sub-angular blocky structure. The soils had high amounts of coarse fragments and sand fractions. The soils were acidic (pH 5.1 – 5.9), rich in organic carbon and are associated with low cation exchange capacity. Based on the characteristics, these forest soils were classified as Dystric Haplustepts, Kanhaplic Haplustalfs, Ustic Haplohumults.

Gabhane *et al.* (2006) studied land evaluation for land use planning of a micro-watershed of Vidarbha region. They reported that land evaluation methods indicate the information on production potential of soils and also present investigation may be useful to suggest the capability and suitability of soils for some important rainfed crops like sorghum, cotton and pigeonpea for efficient soil based agro-technology transfer for better harvest of crops.

Mini *et al.* (2007) characterized and classified the soils of the Mirjan village of coastal agro-ecosystem of Karnataka in relation to topography by remote sensing techniques, ground survey and laboratory analysis. There was gradation in colour from reddish in the higher topographic position to yellowish colour in the lower topographic position. There was an accumulation of clay in low hills and mid lands were with A-Bt-BC horizon sequence. The soil temperature and moisture regimes in area is Isohyperthermic and Ustic, respectively. The pedons on hills and hill ranges and garden lands were classified as Dystrustepts. Pedons of low hills and mid lands showed a better development and were classified into Haplustalfs. The soils of low lands with deep water table were classified into Dystrustepts. The illuvial soils of low lands with shallow water table were classified as Ustifluvents.

2.2 Soil properties

2.2.1 Physical properties of soil

The Black Soils of India (Regur) are characterized by dark colour, low chroma and low organic matter. They are rich in smectitic clay and have shrink-swell potential that can develop deep and wide cracks on drying. The shrink-swell soils (Vertisols) can be differentiated easily from other soil orders by the characteristics signatures reflecting dynamic morphological, physical, chemical and mineralogical properties. According to Schaffer *et al.* (1960), the intense dark colour of the Vertisols is due to the clay organic complexes that are strongly bound to the clay. The nature of clay, organic matter, presence of bases, free calcium carbonate and moisture, influenced colour of black soils of the Chhattisgarh basin (Gawande and Biswas, 1967).

Structure and special physical features are the most striking morphological markers of Vertisols. In surface horizons, Vertisols generally develop a granular structure in the upper 10 cm. This structure is attributed to self-mulching, which is the ability of soil to form small aggregates on the surface due to shrink-swell phenomena (Soil Survey Staff, 1960). Wedge-shaped aggregates and slickensides were first described as lentils by Krishna and Perumal (1948) and subsequently as bicuneate and cuneate structure by de Vos and Virgo (1969). The development of gilgai could be seen as the ultimate state of slickenside development (Kaloga, 1966). According to Landey *et al.* (1982), the cracks in Vertisols of Maharashtra formed during summer get filled with loose surface material during rainy season. On wetting, there is swelling, vertical and lateral stress leading to the formation of gilgai. The degree of expression of cracking and slickenside formation are closely associated with the degree of seasonal wetting and drying periods (Ahmad, 1983).

Gaikwad *et al.* (1974) stated that the red soil is always situated at the top of landscape and the black soils in the valley. This is supported by Prasad *et al.* 1989. Many researchers (Magar, 1990; Nimkar *et al.* (1992), Kadu *et al.*, 1993) reported that in Vertisols of purna Vally, the surface horizons have moderate to strong and medium to coarse angular structure, well developed closely intersecting slickensides forming parallel epipeds with their long axis tilted at 40-45 degrees from horizontal and which breaks in to small angular peds. The peds have shiny pressure faces. Balpande (1993) and Pal *et al.* (2000a) reported that the semi arid climate plays an important role in the formation of deep cracks in Vertisols.

The bulk density of Vertisols varies greatly with changes in soil moisture content and due to their swelling and shrinking nature. According to the bulk density of Vertisols may vary from approximately 1 to 2 Mg m^{-3} depending on the moisture content. The bulk density of Vertisols was also found to vary with the type of black soils and their depth. The average values of the bulk density of deep, medium and shallow soils reported were 1.32, 1.39 and 1.42 Mg m^{-3}, respectively (Bharambe *et al.*, 1986). However, Jadhav (1973) and Birajdar (1982) estimated bulk densities of black soils of Marathwada and Jayakwadi command area and reported in the range of 0.93 to 1.58 and 1.08 to 1.62 g cm^{-3}, respectively. Bhattacharyya and Pal (2003) reported BD of Vertisols of Penninsular Indian in the range of 1.1 to 1.9 M gm^{-3}. The BD value is an important parameter as it takes care of soil size separates, porosity, ESP and hydraulic conductivity since these parameters are highly correlated with BD.

Saturated hydraulic conductivity (SHC) is a very dynamic and variable property. Factors that influence SHC-values are numerous: texture, soil moisture contents, biological activity, electrolyte concentration of the soil solution, soil temperature, depth, management practices and place and place and time of measurements. The SHC indicates high value (6 to 39 mm hr^{-1}) in shallow soils and lower values (2 to 30 mm hr^{-1}) in deep black soils (Bharambe *et al.,* 1986). In the swell-shrink soils of the Purna Valley of central India the SHC rate was 0.3 to 5 mm hr^{-1} and it decreased with increasing depth (Kadu *et al.,* 1993; Balpande *et al.,* 1996). Vertisols with SHC $\geq$ 20 mm hr^{-1} can be considered highly suitable (Category S0 or S1 in Sys *et al.,* 1993) to grow deep rooted crops under rainfed conditions, whereas soils with SHC < 10 mm hr^{-1} are only suitable after their subsoil sodicity has been reclaimed (Kadu *et al.,* 2003). Vertisols have high water storage capacity in root zone because of their usually high content of clay dominantly of 2:1 type of minerals. The available water range of these soils has been reported to be 230 mm in Indian (ICRISAT, 1978) for the upper on meter depth of soil profile.

Many researchers (Magar, 1990; Nimkar, 1990; Kadu *et al.,* 1993) reported that in Vertisols of the Puna Valley, the surface horizons have subangular blocky structure and subsoil horizons have moderate to strong and medium to coarse angular structure, well developed closely intersecting slickensides froming parallelepipeds with their long axis tilted at 40-45 degress from horizontal and which breaks into small angular peds. The peds have shiny pressure faces. Balpande (1993) and Pal *et al.,* (2000) reported that the semi-arid climate plays an important role in the formation of deep cracks in Vertisols. These authors observed that the cracks extend upto the slickenside zone and cuts throughout the slickenside zone in SW part of the Purna Valley, whereas in the NE part, the cracks do not puncture the slickenside zone. This indicates that there may be difference in soil moisture content in these two types of Vertisols of the valley.

Gabhane (1995) reported that the water content both at 33 kPa and 1500kPa tension increases with increase in the silt and clay content individually and also in combination.

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

The Black Soils of India (Regue) are characterized by dark colour, low chroma and low organic matter. They are rich in smectitic clay and have shrink-swell potential that can develop deep and wide cracks on drying. According to Schaffer *et al.* (1960), the intense dark colour of the Vertisols is due to the clay organic complexes that are strongly bound to the clay.

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

Dipak Sarkar *et al.* (1997) reported that the soils of the hilly terrain are very shallow to shallow, yellowish red to dark reddish brown, gravelly sandy loam to sandy clay loam in texture with A-C and A-B-C horizon sequence are classified as, Lithic Ustorthents and Lithic Ustochrepts.

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

Sarkar *et al.* (2001) stated that the soils of upper slopes in toposequence of Chhotanagpur plateau were yellowish red (5 YR 4/6) in colour in the surface layer and dark red (2.5 YR 4/6) in the lower layers while the soils lower slope of the toposequence were light brownish gray to light gray in surface horizon and gray in the lower layers. The colour of the soils in red and laterite region of West Bengal varied from brown to dark red (Nayak *et al.,* 2002). Sarkar Dipak *et al.* (2002) stated that the colour in the surface horizons of soils developed from shale parent material varied from very dark brown (10 YR 2/2) to dark yellowish brown (10 YR 3/4) while the sub-surface horizons were dark brown (10 YR 3/3) to yellowish red (5 YR 4/6). According to Ramprakash and Seshagiri Rao (2002) the colour of the red soils developed on granite - gneiss parent material in Krishna district of Andhra Pradesh varied form dark reddish brown (5YR 3/4) to dark brown (7.5 YR 3/4).

According to Verma *et al.* (2001) the soils in different landscapes showed that the sand and silt constitute major portion in mechanical composition. Particle size distribution in Alfisols of some benchmark soils of West Bengal indicated that a distinct increase in clay content in sub-surface (Bt) horizons (Nayak *et al.,* 2002). The clay content ranged from 44.5 to 50.7 per cent and increased with depth in *sal* growing soils of Dindori district in Madhya Pradesh. Further, these soils were developed over basalt or partly laterised basalt and hence produced higher amount of clay (Patil and Jagdish Prasad, 2004).

The water holding capacity in soils of Haldi Ghati region of Rajasthan were low to medium (17.10% to 37.30%) (Sharma *et al.,* 2001b). The moisture retention in Inceptisols and Entisols of Shahibi basin in Haryana and Delhi at 33 kPa was 8.20 to 19.00 per cent and at 1500 kPa was 3.20 to 8.89 per cent in surface horizons. The low moisture retention was due to lighter texture, low organic matter content and dominance of illite in the clay fraction (Swarnam *et al.,* 2004). Available water content in *sal* growing soils in Dindori district of Madhya Pradesh was found to be positively and significantly correlated with clay and organic matter content (Patil and Jagdish Prasad, 2004). The water holding capacity in soils of Sivagiri micro-watershed in Chittoor district of Andhra Pradesh was ranged from 13.05 to 58.99 per cent. These differences were due to the variation in the depth, clay, silt and organic carbon content in the soils (Thangasamy *et al.,* 2005).

Vaidya and Pal (2002) reported that the hydraulic conductivity of deep black soil varied from 0.3 to 21.8 mm/hr and which was decreased with depth. Kadu *et al.* (2003) reported that evaluation of Vertisols for deep rooted crops on the basis of hydraulic conductivity alone my help in planning and management of soil under semi-arid climate in India.

Arun Kumar *et al.* (2002) noticed that the soils occurring on plains had loam to sandy loam texture and recorded higher clay content than upland soils because of deposition of finer fractions from the uplands. The soils of Chandragiri mandal showed wide textural variations *i.e.*, from sand to clay (plain), sandy loam to clay loam (upland) and sandy clay loam to clay loam (hill slope). These wide variations in soil texture may be due to differences in parent material, physiography *in situ* weathering and translocation of clay (Basava Raju *et al.*, 2005).

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

Sharma *et al.* (2004) studied that the soil of Baun and gopalpur phata and reported that the colour, texture and consistence (dry) range from brown to dark yellowish brown, loamy sand to loam and loose to hard in surface and strongly brown to yellowish brown, sand to clay loam and loose to very hard in subsurface horizons respectively and reported that the soils of various pedons are dark yellowish brown (10YR4/4) to light yellowish brown (10YR6/4) and very dark grayish brown (10YR3/2) to dark brown (10YR3/3) colour.

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

Sub-surface horizons of Neogal watershed in North-West Himalayas exhibited higher clay content as compared to surface horizons due to the illuviation process occurring during soil development. Similarly, the illuviation process also affected the vertical distribution of silt and sand contents. The clay content ranging from 34.4 to 73.4 per cent and it increased with depth. The silt content ranged from 12.8 to 40.0 per cent and sand content was less than 10.0 per cent in soils of micro-watershed in Vidarbha region of Maharashtra (Gabhane *et al.*, 2006).

Thangasamy *et al.* (2005) observed that the clay content varied from 2.50 to 58.30 % and silt content of all the profiles exhibited an irregular trend with depth. Coarse fraction (sand) constitutes the bulk of mechanical fraction, which could be attributed to the dominance of alluvial sandy parent material and he was also reported that the bulk density varied from 1.32 to1.90 Mg m^{-3} and increased with depth which might be due to more compaction in deeper layer caused by over-head weight of the surface soil.

The soils in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh showed wide textural variations (sandy to clay). This variation in soil texture was caused by parent material, topography, *in situ* weathering and translocation of clay (Thangasamy *et al.*, 2005). Textural variations in Shikohpur watershed area are mainly associated with variation in parent material and topography (Sitanggang *et al.*, 2006).

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

Kalbhor (2007) showed that the soils of Parbhani district of Maharashtra comes under subtropical region of Marathwada. It is situated at 409 m above the mean sea level and spread over 19° 76' N Lat 76° 47' E long. It receives assured rainfall with an annual precipitation of 790 mm. the total 62.40 ha area of experimental farm Marathwada Agriculture University Parbhani. The soils studied area dark brown to very dark grayish brown. The dark colour of these soils may be because of humus titaniferrus complex. The fine clayey texture of soil is due to basaltic parent material.

Vaidya and Mali (2008) reported that the soils of kini farm College of Agriculture, Osmanabad are shallow to very shallow (4 to 10.6 cm), Yellowish brown (10YR 5/6 to 10YR 5/8) to radish brown in colour (5YR 4/3 to 5YR 4/4).

Dhale and Prasad (2009) reported that soils and productivity of sweet orange, seven pedons were characterized in Jalna distirct of Maharashtra for their physical, chemical properties, nutritional status of soil. These pedon were Shallow, moderately deep and others were deep to very deep and had their Munsell colour notation in 10 YR/7.5YR/5YR hue with value 3 to 4 and chroma 1 to 4.

Dhale and Prasad (2009) based on variation in physiography, soils and productivity of sweet orange. The surface and sub-surface horizons of pedons are associated with sub-angular blocky structure of varying grade and size but angular blocky structure associated with slickenside is a common feature of sub-soils in Vertisols. In general, peds of sub-surface horizons had pressure faces. The peds of surface horizons exhibited consistency (dry) as hard and friable/firm in moist condition.

Dhale and Prasad (2009) observed that the value of bulk density, in general, increased down the depth. However, relatively higher bulk densities were found in surface layers of P1, P2, P5 and P6 than the sub-surface horizons due to presence of grovels in higher proportion.

Leelavati *et al.* (2009) studied the soil depth varies from deep to very deep and the soil colour on very gentle slopping land varies from yellowish brown (10 YR 5/6) to dark red (2.5 YR 3/6) and in flat land soils showed very pale brown (10 YR 7/3) to reddish grey (5YR 5/2) colour.

Leelavathi *et al.* (2009) revealed that the clay content varied from 2.13 to 55.32% and the silt content in all pedons exhibited an irregular trend with depth and sand constituted the bulk of mechanical fractions, which could be attributed to the dominance and alluvial sandy parent material and the bulk density and different pedons, varied from 1.15 to 1.61 Mg m^{-3} and showed an increasing trend with depth which might be due to more compaction, low organic matter and less aggregation.

Patil (2010) reported that the saturated hydraulic conductivity of soil in Osmanabad district varies from 0.27 to 29.50 cm hr^{-1}. This variation attributed to textural difference. The saturated hydraulic conductivity of soils of Typic Haplusterts (P3, P6 and P7) are ranged from 0.27 to 9.99 cm hr^{-1} and which was decreased with depth except P6 and P7. The hydraulic conductivity of surface soil is less as compared to sub-surface. This variation attributed to application of irrigation water similar observation was reported by Vaidya *et al.* (2007).

Vaidya and Dhawan (2010) reported that the soils of Kini farm college of Agriculture, Osmanabad were clay loam to sandy clay loam in texture and its bulk density (1.67 to 2.11 Mg m^{-3}) varied with decreasing slope.

Likhar and Jagdish Prasad (2011) characterized and evaluated in Nagpur district of Maharashtra for their physical and chemical properties and nutritional status of soils were shallow underlain by saprolite and deep soils had their Munsell colour notation 10YR/2.5Y/7.5YR/5YR hue with value 3 to 4 and chroma 2 to 4.

Likhar and Jagdish Prasad (2011) reported that the surface and sub-surface horizons of pedons are associated with sub-angular block structure of varying grades and sizes but angular blocky structure associated with slickenside is common feature of sub-soils (P_1, P_2 and P_6).

Likhar and Jagdish Prasad (2011) studied that characterized and evaluated in soil of Nagpur district of Maharashtra. The all pedons are associated with Ustic and Hyperthermic, soil moisture and temperature regime have cambic horizon and are hence placed in Inceptisols and Ustepts sub orders owing to Ustic moisture regime. The particle-size distribution and sand/silt ratio show were significantly in soils having different parent materials. The clay content ranged from 24.1 to 68.2 % in different pedons. Basaltic (swelling type) soils had higher bulk density (1.5 to 2.0 Mg m^{-3}). The higher clay in Bt horizon of Typic Haplustalfs was pro by due to translocation of clay from surface horizon.

Soil texture may be defined as the relative proportion of the various soil separates namely sand, silt and clay in a given soil. The proportion of each size group in a given soil cannot be altered easily, that is why texture is considered as a basic property of a soil.

2.2.2 Chemical properties of soil

The studies on soils of Marathwada region indicated the pH of soils between 7.0 to 9.2 while pH of the soils in Latur district varied from 8.3 to 8.9 (Gajbe *et al.*, 1976). Bharambe and Ghonsikar (1985) studied the physico-chemical characteristics of soils in Jayakwadi command area and reported the pH ranging from 7.19 to 9.30. The studies on physico-chemical properties of lateritic soils from Konkan region of Maharashtra indicated the pH of soils from 5.4 to 6.0 (Dongale *et al.*, 1987). Similarly the studies on Bench terraced soils of Konkan indicated the pH from 3.4 to 6.5 in upland terraces and 5.1 to 6.2 in medium terraces (Patil *et al.*, 1987).

The studies on soils of Marathwada region indicated that EC of soils ranged between 0.30 to 0.67 mmhos/cm (Gajbe *et al.*, 1976). Bharambe and Ghonsikar (1985) studied the physico-chemical characteristics of soils in Jayakwadi command area and observed the EC of soils from 0.11 to 3.25 mmhos/cm. While, Dongale *et al.* (1987) noticed that EC of lateritic soils of Konkan region of Maharashtra ranged between 0.029 to 0.059 mmhos/cm^2. The experiment conducted to study the distribution of micronutrients in Tal land soils of Bihar showed that the EC ranged from 0.14 to 0.25 dSm^{-1} (Tiwary and Mishra, 1990). Further, Kanthaliya and Bhatt (1991) studied the soils of humid zone and reported that EC varied from 0.10 to 1.9 dSm^{-1}.

The analysis of twenty representative swell-shrink soil series of Maharashtra showed the pH from 6.8 to 9.1 (Patil and Sonar, 1994). Similarly, Dharkanath *et al.* (1995) studied some important soil series of vestisols in Maharashtra and reported that pH ranged between 7.90 to 9.10. The studies on some soil series of Maharashtra indicated the pH of Vertisols ranging from 7.1 to 8.9. Malewar (1995) evaluated the soils in Marathwada region of Maharashtra and recorded the pH of inceptisols ranging from 8.2 to 8.3 with an average value 8.25 in sugarcane cropping pattern. Chattopadhyay *et al.* (1996) studied nine representative soil profiles from Vindhyan Scarplands of Rajasthan and reported the pH between 5.5 to 6.5, 7.5 to 8.9, 7.2 to 8.8 in hills and hill ridges, in the pediment and the plateau, respectively. Pharande *et al.* (1996) studied the widespread Vertisol and Alfisol soil series of Western Maharashtra and observed the pH from 5.4 to 9.15.

Patil and Sonar (1994) analyzed twenty representative soil series of Maharashtra and reported EC ranging from 0.05 to 1.39 ms/cm. The studies on some important soil series of Vertisols in Maharashtra showed that EC ranged from 0.135 to 3.000 dSm^{-1} (Dharkanath *et al.*, 1995). Further, Dhane and Shukla (1995) analyzed twenty five surface soil samples from different soil series of Maharashtra and reported the EC of Vertisols, inceptisols and Entisols from 0.3 to 1.5, 0.3 to 1.3 and 0.1 to 0.5 dSm^{-1}, respectively.

The experiment conducted to study the micronutrient availability in relation to physico-chemical properties of soil in Marathwada region showed that EC of soils varied from 0.20 to 0.30 with an average value of 0.25 dSm^{-1} (Malewar, 1995). Further, Chattopadhyay *et al.* (1996) studied nine representative soil profiles from Vidhyan scarplands of Rajasthan and noticed the EC from 0.19 to 0.38, 0.32 to 0.45 and 0.80 to 1.08 dSm^{-1} in soils of the hills and hill ridges, pediment and plateau, respectively. Five profiles of vetisols derived from different parent materials were studied by Murthy *et al.* (1997) and reported the EC from 0.10 to 1.20 dSm^{-1}. The lateritic soils of Konkan were found to vary in EC from 0.02 to 0.07 dSm^{-1}, (Diwale and Chavan, 1999). Padole and Mahajan (2003) studied the swell-shrink soils of Vidharbha region and reported the EC of these soils from 0.13 to 1.54 dSm^{-1}.

Sharma *et al.* (2003) studied some soils of Nagpur district in semi-arid region of Rajasthan and reported the EC from 0.11 to 0.44 dSm^{-1}. The studies on the elemental composition of humic acid and fulvic acid in the soils of Marathwada indicated the EC varying from 0.12 to 0.86 dSm^{-1} (Waikar *et al.*, 2004). Dwivedi *et al.* (2005) observed EC in the range of 0.05 to 1.41 dSm^{-1} and 0.08 to 1.55 dSm^{-1} in Leh and Kargil district, respectively while studying the status of available nutrients in soils of cold region of Ladakh.

Waikar *et al.* (2003) reported the pH of South Central Maharashtra soils ranging between 6.18 to 8.44. The evaluation of soils of Konkan region indicated the pH ranging from 3.90 to 6.28 in very high rainfall lateritic soils and 5.85 to 7.75 in very high rainfall non lateritic soils (Patil and Meisheri, 2004). The studies on soils of Marathwada region of Maharashtra showed that the soil pH ranged from 6.12 to 8.84 (Waikar *et al.* (2004). Similarly, Dwivedi *et al.* (2005) studied the soils of cold arid region of Ladakh and reported the pH from 5.94 to 10.12 and 6.57 to 9.47 in Leh and Kargil districts, respectively.

Kalbhor (2007) reported that the soils of Marathwada Agriculture University, Parbhani were placed under the pH of soils was ranged between 7.68 to 8.37 with an average 7.90. The higher pH was found as 8.37 in Typic Haplustert. It is due to basic soil parent material derived from basalt rock. The basaltic rocks are basic rocks containing ferromagnesian minerals and titaniferrous compound which on weathering release basic cations, so soil become alkaline.

Kalbhor (2007) reported that the soil salts in the farm of Marathwada Agriculture University, Parbhani soils were distributed in the range of 0.212 to 0.698 dsm^{-1}. The salt concentration is due to low infiltration rate in presence of sufficient clay content which has restricted the salt of present. On the basis of ratings suggested for EC, all the farm soils of these groups were in the safe limit.

Dhale and Prasad (2009) studied that the pH values, the soil of P1, P2, P3 and P4 are categorized as moderately alkaline. Pedon P5, P6 and P7 had pH ranging from 8.2 to 8.9 in different horizons. Thakare and Ingle (2010) reported that the soil sampled in post-monsoon 2006 and in pre-monsoon 2007 showed the pH value ranging from 7.5 to 8.5 and 7.6 to 8.5, respectively. The recorded difference in the surface and subsurface soils was limited to 0.4 units only. Horizon wise variation in soil pH indicated slightly increase with increase in depth.

Thakare and Ingle (2010) reported that the values of electrical conductivity of the samples in post monsoon 2006 and pre-monsoon 2007 ranged respectively from 0.12 to 1.32 and 0.14 to 1.47 dSm^{-1}. The depthwise variation in EC (dSm^{-1}) presented below indicated increase with an increase in depth from surface to subsurface layers.

Selvaraj and Naidu (2012) reported that pH of soils varied from 6.2 to 7.9 in uplands and 6.2 to 9.0 in plains. The higher pH in soils of plains may be due to more accumulation of bases removed from uplands.

2.2.2.1 Macronutrient status

Gajbe *et al.* (1976) analyzed the soils of Marathwada region and reported the available phosphorus in soils from Latur varied from 25.6 to 51.2 kg ha^{-1}. Further, Bharambe and Ghonsikar (1985) recorded the available phosphorus from 7.92 to 31.36 kg ha^{-1} in soils from Jayakwadi command area. The lateritic soils in Konkan region of Maharashtra contained the available P_2O_5 ranging from

5.15 to 10.30 kg ha^{-1} (Dongale *et al.,* 1987). While, the Bench terraced soils of Konkan region were reported to contain available P_2O_5 from 5.2 to 16.5 kg ha^{-1} and 5.2 to 15.5 kg ha^{-1} in upland terraces and medium terraces, respectively (Patil *et al.*, 1987).

The soils from Latur were analysed by Gajbe *et al.* (1976) and reported the available potassium from 683 to 1344 kg ha^{-1}. Bharambe and Ghonsikar (1985) studied the soils in Jayakwadi command area and recorded available K from 280 to 888 kg ha^{-1}. The lateritic soils in Konkan region were found to contain the available K_2O from 168.0 to 324.8 kg ha^{-1} (Dongale *et al.*, 1987). While Bench terraced soils of Konkan region were found to contain higher available K_2O ranging from 162.8 to 854.9 kg ha^{-1} in upland terraces and 162.8 to 814.4 kg ha^{-1} in medium terraces (Patil *et al.*, 1987).

Lateritic soils in Konkan region found to contain available nitrogen from 248.1 to 423.8 kg ha^{-1} (Dongale *et al.*, 1987). Similarly, some soils of sub-humid zone are reported to contain available N from 112 to 466 kg ha^{-1} (Kanthaliya and Bhatt, 1991). However, the swell-shrink soil series of Maharashtra showed comparatively lower available nitrogen ranging from 115 kg ha^{-1} in Kandegaon to 228 kg ha^{-1} in Aroli series (Patil and Sonar, 1994). Similarly, five soil profiles from flood plains of Bangaladesh showed available nitrogen ranging from 30 to 202 mg kg^{-1} (Khan *et al.*, 1997).

The soils of sub humid zone contained higher values of available P_2O_5 ranging from 7.6 to 138.3 kg ha^{-1} (Kanthaliya and Bhatt, 1991). Bhogal *et al.* (1993) reported higher values of available P ranging from 6.4 to 70.0 kg ha^{-1} in Aquic ustifluvents and udifluvents. The coastal soils of Sundarban in West Bengal found to contain the available P_2O_5 from 14 to 85 kg ha^{-1} (Maji *et al.*, 1993). Murthy and Srivastava (1994) studied the fertility status in relation to terrace management at Majhera farm in lower Shivaliks. They reported the available P content from 2.0 to 47.3 with mean value of 22.4 kg ha^{-1}, 9.9 to 80.08 with mean of 45.2 kg ha^{-1} and 20.7 to 37.4 with mean of 29.6 kg ha^{-1} in lower terrace; middle terrace and upper terrace, respectively, further, Patil and Sonar (1994) studied twenty representative swell-shrink soil series of Maharashtra and reported the available P ranging from 5.08 to 16.38 kg ha^{-1} with mean value of 8.72 kg ha^{-1}.

Kanthaliya and Bhatt (1991) noticed that the available K_2O status varied from 175 to 2511 kg ha^{-1} in some soils of sub-humid zone. While, the

Acquic ustifluvents and udifluvents from Bihar contained the available K_2O from 24.7 to 540.0 kg ha^{-1} (Bhogal *et al.*, 1993). Joplin *et al.* (1993) analysed some Alfisols and showed the available K from 43 to 375 ppm, 47 to 325 ppm and 48 to 177 ppm in east khasi hills, west khasi hills and Jaintia hills, respectively. The soil fertility status in relation to terrace management at Majhera farm in lower shivaliks was studied by Murthy and Srivastava (1994) and reported the higher available K from 300 to 575 kg ha^{-1} with mean value of 454 kg ha^{-1}, 360 to 1020 with mean value of 567 kg ha^{-1} and 405 to 555 with an average of 457 kg ha^{-1} in lower, middle and upper terrace, respectively.

The swell-shrink soil series of Maharashtra showed the higher available K content from 224 to 909 kg ha^{-1} (Patil and Sonar, 1994). However, the lateritic soils of Konkan were found to contain lower values of available K_2O ranging from 94.9 to 336.8 kg ha^{-1} (Diwale and Chavan, 1999). Dhage *et al.* (2000) studied the soils of Shevgaon tahsil and noticed that the available K ranged from 168.0 to 1120.0 kg ha^{-1}.

The studies conducted on soils of Marathwada indicated the available P_2O_5 ranging from 16.0 to 76.8 with an average of 37.7 kg ha^{-1} in Vertisols / Inceptisols (Malewar, 1995). While, the lateritic soils of Konkan showed the available P_2O_5 ranging from 4.9 to 23.9 kg ha^{-1} (Diwale and Chavan, 1999). Similarly, Dhage *et al.* (2000) studied the soils of Shevgaon tahsil and reported P_2O_5 ranging from 7.39 to 25.53 kg ha^{-1}. The analysis of some soils of Marathwada region showed the available P content from 10.0 to 19.1 kg ha^{-1} (Waikar *et al.*, 2004). Similarly, Dwivedi *et al.* (2005) reported the available P ranging from 2.35 to 25.66 kg ha^{-1} and 2.50 to 137.40 kg ha^{-1} in Leh and Kargil districts, respectively. Meena *et al.* (2006) studied some soils of Tonk district of Rajasthan and reported the P_2O_5 from 9.2 to 65.2 kg ha^{-1}.

Diwale and Chavan (1999) studied lateritic soils of Konkan and reported available nitrogen ranging from 236.2 to 448.9 kg ha^{-1}. While, the soils of Shevgaon tahsil in Ahmednagar district varied in available nitrogen from 59.58 to 228.92 kg ha^{-1} (Dhage *et al.*, 2000). Similarly, the soils of Marathwada varied in available nitrogen from 137 to 251 kg ha^{-1} (Waikar *et al.*, 2004). Meena *et al.* (2006) studied the soils of Tonk district of Rajasthan and reported the available nitrogen ranging from 125 to 555 kg ha^{-1}.

Waikar *et al.* (2004) recorded that the soils of Marathwada region contained the available K from 303 to 512 kg ha^{-1}. Similarly, the available K varied from 11.0 to 496 kg ha^{-1} and 103.00 to 861.30 kg ha^{-1} in soils from Leh and kargil districts, respectively (Dwivedi *et al.*, 2005). Meena *et al.* (2006) studied some soils of Tonk district of Rajasthan and reported the K from 105 to 1059 kg ha^{-1}.

2.2.2.2 Micronutrients status

Malewar and Randhawa (1978) studied the distribution of DTPA extractable Fé, Ze, Mn, and Cu in Marathwada soils and noticed that the distribution of Fe and Zn in the range of 6.6 to 8.6 mg kg^{-1} and 4.40 mg kg^{-1}, respectively. They also found that the Cu and Mn ranges from 1.2 to 7.4 and 13.3 to 65.2 mg kg^{-1}, respectively in different soils of Marathwada.

Table 2.1: Ratings of micronutrients for calcareous clay soil (Jones, 1980).

Sufficency category	DATA Extractable element (mg kg-1 soil)			
	Zn	Fe	Cu	Mn
Low	<0.5	<2.0	<0.5	<1.8
Medium	0.5-<1	2.0-3.9	-	-
High	>1.0	>4.0	>0.5	>1.8

The Bench terraced soils of Konkan showed the content of available Fe from 10.2 to 19.2 ppm with an average of 12.46 ppm in upland terraces and 6.8 to 16.4 ppm with an average of 11.21 ppm in medium terraces (Patil *et al.*, 1987). The iron content in rice growing soils from orissa was reocrded in the range of 5.4 to 356.0 ppm (Sahu *et al.*, 1990). Tiwary and Mishra (1990) studied the distribution of micronutrients in Tal land soils of Bihar and recorded the available Fe content ranging from 4.2 to 11.5 ppm. Studies on twenty soil series of india indicated the higher availability of Fe ranging from 7.3 to 199.1 ppm (Singh and Sekhon, 1991). Similarly, Aquic ustifluvents and udifluvents from Bihar also contained higher amount of available Fe from 1.3 to 352.0 ppm (Bhogal *et al.*, 1993).

The studies on Bench terraced soils of Konkan indicated the available Mn content from 4.8 to 200 ppm with an average value 36.35 ppm in up land terraces and 6.0 to 102.4 ppm with an average of 45.13 ppm in medium terraces (Patil *et al.*, 1987). The available Mn content in rice growing soils was studied by Sahu *et al.* (1990) and reported in the range from 1.3 to 212.0 ppm. Tal land soils of Bihar found to contain the available Mn varying from 4.4 to 27.4 ppm (Tiwary and Mishra, 1990). The DTPA extractable Mn content was ranged from 10.2 to 113.5 ppm in twenty soil series of India (Singh and Sekhon, 1991).

The DTPA extractable Zinc in some Benchmark soil series of India varied from 0.37 to 0.67 ppm (Singh and Sekhon, 1993). Murthy and Srivastava (1994) studied the soil fertility status in relation to terrace management at Majhera farm in lower shiwaliks and reported comparatively higher values of Zn from 11.7 to 19.5 ppm with a mean value of 13.9 ppm, 11.5 to 20.0 ppm with an average of 13.2 ppm and 11.7 to 15.2 with mean of 13.3 ppm in lower, middle, and upper terrace, respectively. The swell-shrink soils of Maharashtra were found to contain the available Zn from 0.58 to 1.7 ppm with a mean of 0.87 ppm (Patil and Sonar, 1994).

The swell-shrink soils of Maharashtra found to contain DTPA extractable Fe from 6.1 to 26.0 ppm with an average of 13.1 ppm (Patil and Sonar, 1994). The studies conducted with nine representative soil profiles from Vidhyan scarplands of Rajasthan indicated the available Fe content from 5.0 to 24.9 ppm in soils of the hills and hill ridges, 4.1 to 7.2 ppm in the pediment and 1.5 to 6.8 ppm in the plateau (Chattopadhyay *et al.*, 1996).

Dhane and Shukla (1995) reported that soil series of Maharashtra ranged in Zn from 0.3 to 0.6 mg kg^{-1}. Chattopadhyay *et al.* (1996) evaluated nine representative soils profiles from Vindhyan scarplands of Rajasthan for status of available micronutrients and recorded the available Zn from 1.6 to 3.7 ppm in soils of the hills and hill ridges, 1.0 to 1.4 ppm in the pediment and 0.5 to 1.4 ppm in the plateau. Further, comparatively lower values of DTPA extractable zinc from 0.13 to 0.55 ppm were recorded in Inceptisol soil series of Maharashtra (Nipunage *et al.*, 1996). The content of available Zn in Vertisol and Alfisol soil series of Western Maharashtra varied from 0.21 to 3.94 ppm and 0.08 to 4.36 ppm, respectively (Pharande *et al.*, 1996).

The Vertisols of Maharashtra were ranged from 0.3 to 0.6 mg kg^{-1} in available Cu (Dhane and Shukla, 1995). The availability of Cu in Inceptisols in Marathwada ranged from 1.7 to 6.6 ppm with an average of 3.6 ppm (Malewar, 1995). Chattopadhyay *et al.* (1996) noticed the available Cu content from 0.7 to

6.7 ppm in soils of the hills and hill ridges, 0.5 to 1.1 ppm in the pediment and 0.7 to 1.2 ppm in the plateau from the scarpland profiles of Rajasthan. The DTPA extrctable Cu content was recorded to vary from 1.0 to 4.7 ppm in Inceptisols of Maharashtra (Nipunage *et al.*, 1996). Acid Alfisols of Meghalaya under rice cultivation contained comparatively higher values of available Cu ranging from 1.0 to 37.0 mg kg^{-1} (Nongkyrih *et al.*, 1996). While, another studies in Maharashtra indicated DTPA Cu content from 1.30 to 6.30 and 0.40 to 6.7 ppm, respectively in Vertisols and Alfisols of Western Maharashtra (Pharande *et al.*, 1996). Similarly the studies on the Micronutrient research and sustainable agricultural productivity in India showed the available Cu content from 0.49 to 2.27 mg kg^{-1} (Takkar, 1996).

The Mn availability in Inceptisols from Marathwada ranged from 14.9 to 28.0 ppm with an average value of 19.9 ppm (Malewar, 1995). Chattopadhyay *et al.* (1996) noticed that available Mn content from 4.2 to 25.7 ppm in soils of the hills and hill ridges, 5.5 to 10.4 ppm in the pediment and 3.4 to 11.5 ppm in the plateau from vidhyan scarplands of Rajasthan. Nipunage *et al.* (1996) noticed that available Mn content from 4.1 to 46.5 ppm in inceptisol soil series of Maharashtra. Acid Alfisols of Meghalaya ranged in available Mn from 4.0 to 169 ppm (Nogkynrih *et al.*, 1996). While, Pharande *et al.* (1996) reported the available Mn from 7.3 to 40.1 ppm and 1.96 to 147.7 ppm in Vertisol and Alfisol soil series, respectively. Takkar (1996) reported the available Mn from 12.4 to 86.8 ppm in soils from India. The Vertisols derived from different parent materials showed the available Mn content from 13 to 157 ppm (Murthy *et al.*, 1997). While, Singh *et al.* (1997) showed that the Entisols of Meghalaya varied in available Mn from 1.2 to 52.0 mg kg^{-1}.

Nipunage *et al.* (1996) studied the distribution of total and DTPA micro-nutrient in Inceptisol soil series of Maharashtra and observed the DTPA extractable Fe from 2.9 to 10.1 ppm. The acid Alfisols of Meghalaya under rice cultivation was found to contain the available Fe from 26 to 99 ppm (Nongkyhrih *et al.*, 1996). The Vertisols and Alfisols soil series of Western Maharashtra contained the DTPA extractable Fe from 3.52 to 19.44 ppm and 3.62 to 63.00 ppm, respectively (Pharande *et al.*, 1996). Takkar (1996) studied on sustainable agricultural productivity in India and reported that Fe ranged from 9.1 to 59.0 mg kg^{-1}, Yelvikar *et al.* (1996) studied on vertic soils and their relation with soil properties and reported the Fe ranging from 0.75 to 8.44 mg kg^{-1}.

Bellakki and Badanur (1997) conducted a field experiment on Vertisol at Bijapur under dry land condition and reported that the incorporation of organic sources of nutrients (FYM and sunheamp as a green manure) either alone or in combination with fertilizers (NPK, 50 per cent and 100 per cent) recorded higher DTPA-extractable micronutrients (Zn, Fe, Cu, and Mn) in surface and subsurface soils. This might be attributed due to addition of organic matter which enhanced the microbial activity in the soil. Due to the consequent release of complex organic substances (chelating agents) and the addition of micronutrients through the organic sources which improve the micronutrient status of soil (Bellakki *et al.*, 1998).

The studies on soils in Bundelkhand district indicated available Mn from 2.16 to 13.99 mg kg^{-1}. Dhage *et al.* (2000) noticed available Mn content from 6.98 to 45.83 ppm in the soils of Shevgaon Tahsil. While it ranged from 3.8 to 141.7 mg kg^{-1} in mandarin orchards of Sikkim (Patiram *et al.*, 2000). Sharma *et al.* (2003) found that some soils of Nagpur district in semi-arid region of Rajasthan varied in available Mn from 3.5 to 6.9 ppm. The DTPA extractable Mn content from 0.29 to 68.6 ppm was recorded in very high rainfall lateritic soils and 0.29 to 72.35 ppm in very high rainfall non-lateritic soils from Konkan region of Maharashtra (Patil and Meisheri, 2004). The available Mn content in soils of cold arid region of Ladakh varied from 0.20 to 32.17 ppm and 0.34 to 4.74 ppm in Leh and Kargil district, respectively (Dwivedi *et al.*, 2005). Different soil sub-groups of Punjab showed the available Mn between 3.11 ppm in the siwalik hills and 6.85 ppm in piedmont plains (Hundal *et al.*, 2006). Meena *et al.* (2006) studied some soils of Tonk district of Rajasthan and reported the available Mn between 6.45 to 45.25 mg kg^{-1}.

Dhage *et al.* (2000) reported that the soils of Shevgaon tahsil ranged in Zn from 0.10 to 2.82 ppm. The soils of Nagpur district in semi-arid region of Rajasthan were found to contain available Zn from 0.1 to 1.6 ppm (Sharma *et al.*, 2003). While, some representative soils of Konkan region contained the available Zn from 0.29 to 3.25 mg kg^{-1} in very high rainfall lateritic soil and also in non-lateritic soil (Patil and Meisheri, 2004). The status of available nutrients in soils of cold arid region of Ladakh was studied by Dwivedi *et al.* (2005) and reported the DTPA extractable Zinc from 0.06 to 16.30 mg kg^{-1} and 0.14 to 5.17 mg kg^{-1} with an average value of 1.03 and 1.20 mg kg^{-1} in Leh and Kargil districts, respectively. Further, comparatively lower values of available Zn were recorded ranging from 0.64 to 1.92 ppm in active recent flood plains 0.35 to 3.49 ppm in Alluvial plains partly salt affected, 0.51 to 9.05 ppm in Alluvial plains with sand dunes, 0.40 to 4.07 ppm in piedmont plains, 0.35 to 1.05 ppm in shiwaliks and 0.19 to 16.47 in alluvial plains (Hundal *et al.*, 2006). Meena *et al.* (2006) studied some soils of Rajasthan and reported the Zn content from 0.19 to 1.93 kg ha^{-1}. The swell-shrink soils of Maharashtra showed the available Cu from 1.3 to 6.1 ppm with an average of 3.0 ppm (Patil and Sonar, 1994).

The status of micronutrients in Indian soils is found to be depleting at alarming rate widespread deficiency of zinc in Punjab soil and zinc and iron deficiency in Maharashtra soils are well documented (Yadav, 2005 and Patil, 1997). Further detail account of micronutrient reports is review under following paragraphs.

Yadav (2005) indicated that out of 46 soil sample of college of Agriculture Latur from 10 (21.74 per cent) samples are medium in zinc status and rest 36 (78.26 per cent) soil samples were rated as high in zinc. Wide range deficiency of available iron was found at college farm only 40-35 percent soils were medium in DTPA extractable Fe. Similarly, copper content in the soils of colleges farm found medium (10.87%) to high (89.13%) DTPA extractable managese was observed to be high in soils of college farm.

Yadav (2005) observed that out of 46 soil samples of College of Agricultural Latur from 10 (21.74%) samples are medium in zinc status and rest 36 (78.26%) soil samples were rated as high in zinc content. He also found that, from copper content in the soil are medium (10.87%) to height (89.13%).

2.3 Soil organic, inorganic and total carbon status

Lee *et al.* (1949) stated that added nitrogen was of principal important for preventing excessive carbon loss. The most important factor affecting composting and rate of organic matter decomposition was C:N ratio. Since, that the microorganisms utilized by 30 parts by weight of carbon for each part of nitrogen. C:N ratio of 30 was considered most desirable for efficient composting. The C:N below 26 resulted in increasing loss of nitrogen as ammonia, while ratio above 35 lead to progressively longer time for composting.

The majority of Vertisols are neutral to alkaline in reaction because, they are mostly derived from calcareous or base-rich parent materials. In these calcareous soils, the $CaCO_3$ content may be either uniform throughout the profile depth or it may increase in the subsurface horizons (Raychaudhari *et al.,* 1963., de Vos and Virgo, 1969). Black soils of the Purna Valley have been reported as calcareous (2 to 20 per cent $CaCO_3$) (Magar, 1990; Kadu *et al.,* 1993; Balpande *et al.,* 1996) and in general $CaCO_3$ content increases with depth (Balpande *et al.,* 1996). The rate of formation of $CaCO_3$ in black soils is 0.25 mg per 100 gm of soil per year in the first 100 cm of the profile (37.5 kg $ha^{-1}yr^{-1}$) for mean bulk density of 1.5 Mg m^{-3} to 1 m depth.

Russell (1973) observed that due to presence of crop, influences CO_2 production and emission from the soil. Production of CO_2 was approximately 2 to 3 fold greater in cropped soil compared to bare soil. Within different crop also there is variability in CO_2 production.

Gajbe *et al.* (1976) analyzed soils of Marathwada and reported the organic carbon in soils of Latur district between 0.47 to 0.84 per cent. The soils of Jayakwadi command area were found to contain organic carbon from 0.30 to 2.22 per cent (Bharambe and Ghonsikar, 1985). While the lateritic soils of Konkan region ranged in organic carbon from 0.57 to 2.13 per cent (Dongale *et al.*, 1987). Further, the Bench terraced soils of Konkan region ranged in organic carbon from 0.81 to 2.79 with an average 1.35 per cent in upland terraces and 1.05 to 2.79 with a mean of 1.60 per cent in medium terraces (Patil *et al.*, 1987). Sahu *et al.* (1990) studied rice growing soils from Orissa and observed the organic carbon from 0.13 to 1.43 per cent. The Tal land soils of Bihar were found to contain organic carbon from 0.43 to 0.62 per cent (Tiwary and Mishra, 1990).

Kowalenko and Ivarson (1978) observed that the effect of low pH on soil microbial activity, which contributes to respiration and consequently lower CO_2 evolution, further increase in CO_2 evolution with increase in pH. However, soil pH beyond 7.0 adversely affected CO_2 emission and at pH 8.7, CO_2 emission reduced by 18 per cent compared to that of at pH 7.0 and when, the pH increased to 10.0 the extent of reduction in CO_2 emission was 83 per cent.

Mc Gill *et al.*, (1981) observed organic carbon in soil is an immediate source of carbon for soil microorganisms, which in turn to emit CO_2. Large quantities of organic manure that are added to agriculture soil every year for supplying nutrient to crop may contribute significantly to CO_2 emission.

The soils in Jayakwadi command area were found to contain calcium carbonate from 1.12 to 16.81 per cent (Bharambe and Ghonsikar, 1985). Tal land soils of Bihar contained the calcium carbonate from 1.8 to 2.5 per cent (Tiwary and Mishra, 1990). However, some soils of sub humid zone of Rajasthan found to contain calcium carbonate from 0.25 to 16.0 per cent (Kanthaliya and Bhatt, 1991). Further, Singh and Sekhon (1993) studied some Benchmark soil series of India and recorded calcium carbonate from 1.5 to 11.6 per cent. Similarly, the studies on twenty representative swell-shrink soil series of Maharashtra indicated the calcium carbonate from 0.2 to 14.4 per cent (Patil and Sonar, 1994).

Fernandez and Kosian (1987) reported that descriptive statistics for soil air CO_2 concentration and soil temperature during the study period. Most of the six sampling location used were shallow soil without a C horizon, therefore CO_2 concentrations in the O horizon were generally low, which we anticipated due to the large porosity of forest floor materials and subsequent rapid exchange of gases with the atmosphere. There was a trend for higher temperatures in the O horizon, but these temperatures were not significantly different between B and C horizons throughout the growing season. These soils had relatively low soil air CO_2 concentrations when compared to some of the published data such as those reported by Cosby *et al.* (1985) for a Virginia and German forest soil where seasonal maximums ranged near 3 %. The lower soil air CO_2 in this study could be due to the cooler climate in main or differences in the quality of organic materials. Measurements over a number of growing seasons will be necessary to quantify regional differences in soil air CO_2 as well as year to year variations.

Gupta and Tripathi (1989) explain the CO_2 evolution pattern and its intimate relationship with type of organic material. Bhatia and Shukla (1982) concluded, from result of permanent manorial trial at Kanpur that the continuous application of FYM as a source of organic material for five years helped in maintaining and further improving physical properties of corded alluvial soils.

The relationship between organic carbon and available nutrients in some soils of sub-humid zone was studied by Kanthaliya and Bhatt (1991) and reported the organic carbon from 0.14 to 1.50 per cent. Bhogal *et al.* (1993) studied the Aquic ustifluvents and udifluvents in Bihar and reported the organic carbon ranging from 0.1 to 2.0 per cent. While coastal soils of Sundarban in West

Bengal found to contain the organic carbon from 0.20 to 2.17 per cent (Maji *et al.*, 1993). Singh and Sekhon (1993) studied Benchmark soil series of India and reported the organic carbon from 0.10 to 1.29 per cent. Twenty representative and widely spread swell-shrink soil series of Maharashtra were recorded to contain the organic carbon from 0.37 to 0.72 per cent (Patil and Sonar, 1994). Similarly, the organic carbon content in inceptisols in Marathwada region of Maharashtra ranged from 0.38 to 1.36 per cent with an average of 0.82 per cent (Malewar, 1995). Gupta and Rao (1994) were the first to estimate the SOC stock which was reported to be 24.3 Pg (1 Pg = 1015 g) for the soils ranging from surface to an average subsurface of 44 to 186 cm with the database of 48 soil series. However, the estimate was based on a hypothesis of the enhancement of OC level judging by success stories of afforestation program on some unproductive soils. Later Velayutham *et al.* (2000) reported the total organic carbon stock over various depth limits such as 0– 30 cm, 0–50 cm, 0–100 cm, 0–150 cm following the comprehensive account of soil database of the entire country. Later this estimate on TC stock was revised by Bhattacharyya *et al.* (2000), who reported nearly 9.8 Pg and 30 Pg SOC stock in Indian soils at 0–30 cm and 0–150 cm soil depths, respectively. The estimate of SOC stock in black cotton soils (BCS) (Vertisols and their intergrades) of Maharashtra was reported separately. It indicates a value of 54 and 171 Gg (1 Gg = 109 g) at 0–30 cm and 0–150 cm soil depth, respectively (Bhattacharyya, Pal, Velayutham, Chandran and Mandal 2001). The SOC stock for BCS of Maharashtra accounts for only 0.008% of the total SOC stock of the entire country. The SOC stock of the Indo-Gangetic Plains (IGP) reported earlier (Bhattacharyya *et al.* 2000) and revised later (Bhattacharyya *et al.* 2004; Bhattacharyya and Pal 2003) constitutes 6.06% of the total SOC stock of India.

Some important soil series of Vertisols in Maharashtra were reported to contain higher amount of calcium carbonate ranging from 37.5 to 202.5 g ha^{-1} (Dharkanath, *et al.*, 1995). The soils of Marathwada region of Maharashtra contained the calcium carbonate from 0.00 to 11.5 per cent with an average value of 6.25 per cent (Malewar, 1995). However, the Vertisols in Karnataka ranged in calcium carbonate from 42 to 87 g ha^{-1} (Yerriswamy *et al.*, 1995). Similarly, the soils of Vindhyan scarplands of Rajasthan contained the calcium carbonate from 1.0 to 122.5 g ha^{-1} (Chattopadhyay *et al.* 1996). Pharande *et al.* (1996) observed the calcium carbonate content from 2.0 to 26.5 per cent in Vertisols and Alfisols soil series of Western Maharashtra. The evaluation of five soil profiles from flood plains of Bangladesh indicated calcium carbonate content from 0 to 85 g ha^{-1} (Khan *et al.*, 1997). Further Murthy *et al.* (1997) analyzed Vertisols derived from different parent materials and reported very high value of calcium carbonate ranging from 65 to 460 g ha^{-1}. While, the entisols of Meghalaya showed the calcium carbonate ranging from 2 to 28 g kg^{-1} (Singh *et al.*, 1997).

The Vertisols and Alfisols soil series of Western Maharashtra were found to contain the organic carbon from 0.20 to 2.09 per cent (Pharande *et al.*, 1996). Diwale and Chavan (1999) studied the lateritic soils of Konkan region and recorded the organic carbon between 0.30 to 2.03 per cent. While the soils of Nagpur district in semi-arid region of Rajasthan contained the organic carbon from 0.10 to 0.30 per cent (Sharma *et al.*, 2003). The evaluation of representative soils of Konkan region showed the organic carbon ranging from 0.39 to 2.46 per cent in very high rainfall lateritic soils and 0.51 to 1.95 per cent in very high rainfall non lateritic soils (Patil and Meisheri, 2004).

Patil (1997) observed that the sweet orange orchards of Marathwada region and reported that soils were Entisols, Inceptisols and Vertisols. These soils are mostly clayey in texture and alkaline in soil reaction while, Bharambe *et al.* (1999) analyzed soils of Majalgaon canal command area and found that the organic carbon varied from 0.23 to 0.81 percent in surface layers. Further, Sharma and Bali (2000) reported the organic carbon content (6.8g kg^{-1}) increase in caltiated soils over uncultivated soils (5.1g kg^{-1}) and it was higher in surface soils as compared to sub-surface soils. The soils under different cropping system varied from 0.13 to 0.20 dSm^{-1} and pH from 7.1 to 7.6 these values were significantly higher than that of uncultivable soils.

Bouma *et al.* (1997) observed that the temperature has a marked effect on CO_2 evolution from the soil. They found a strong relationship between CO_2 evolutions and mean daily temperature. The CO_2 evolution at 100 C was not observed, while logarithmic increase in CO_2 evolutions between 200 C to 400 C while above 500 C it declines rapidly. Further they found that, at higher temperature partial inhibition of microbial respiration, which was attributed to inactivation of biological oxidation system. Bunt and Rovira (1954) found increased CO_2 evolution with rise in temperature above 500C. Maximum CO_2 evolution rate was noted in mid-July (190 kg CO_2 /ha/day), which was attributed to the increasing role of root activity and organic matter decomposition with the increase in temperature. Increase in C would increase CO_2 evolution from the soil that accelerated the depletion of soil carbon and soil fertility. The temperature from 15 to 25 C for CO_2 emission in forest suggested that CO_2 emission was controlled primarily by soil biological activity.

Recent studies on ferruginous (red) soils (Saikh *et al.* 1998) and associated red and black soils (Bhattacharyya and Pal 1998 indicate that the SOC content sharply declines when put to cultivation. Reduction of SOC level is significant even within 15 to 25 years of cultivation. The hypothesis is that irrespective of the initial OC levels of these red soils, there is a tendency to reach the quasi-equilibrium value (QEV) of 1 to 2% SOC. These values could be as high as 2–5% for black soils (Bhattacharyya and Pal 1998). Such studies are limited to a specific geographical region and it is not possible to arrive at a generalized view about carbon carrying capacity of the soils because quality of soil substrate and its surface charge density (SCD) vary from one place to another.

Bhattacharyya and Pal (1998) reported 2–5% of SOC in the black soils of Mandla and Dindori districts, Madhya Pradesh. Dalal and Carter (2000) indicated the scope of higher SOC content in the shrink-swell soils of Australia. To find out the sufficient and deficient zone for SOC in different agroecoregions, Velayutham *et al.* (2000) adopted the lower limit of the QEV of 1%. In view of higher SCD of the dominant soils in the SAT, considering a QEV of 2% of SOC at 0–30 cm soil depth, the SOC stock is 10.5 Pg for an area of 116.4 million hectares (ha). This value is more than 3 times the existing SOC stock of SAT (Bhattacharyya *et al.* 2000). It, therefore, appears that effective sequestration processes can increase the SOC stock by 3 times or more, suggesting that the SAT could be fruitfully prioritized for carbon management in the Indian subcontinent.

The SOC, SIC and TC stocks of the study area in black soils (14830.26 kha) in HM spots. Total SOC stock is 0.4719 Pg, which is about 0.03 Pg/(million ha). This value [0.03 Pg/(million ha)] is higher than the value of SOC [0.024 Pg/(million ha)] reported on the basis of soils data of 1980s (Bhattacharyya *et al.* 2000). It shows that during the last 20–25 years, improved management must have helped sequestering more SOC in the black soils of Indian SAT. The SOC, SIC and TC stocks at 0–30 and 0–150 cm soil depths are also which clearly indicate an inverse relationship with the SOC and the SIC. Figure 3.1b shows relative proportion of SOC and SIC over TC in black soils. The relative proportion of SOC (over TC) decreases from 40 to 28% from 0–30 cm to 0–150 cm soil depths. The corresponding figure for SIC increases from 60% to 72%. This is due to decrease in SOC content down the depth of profile. Conversely, $CaCO_3$ concentration increases down the depth contributing to more SIC at soil depth 0–150 cm than at 0–30 cm.

Senapati and Behera (2000) observed that, the effect of moisture levels on evolution of CO_2 and found maximum CO_2 evolution at 60 per cent maximum water holding capacity. This CO_2 evolution rate was found in increasing trend up to 8 week period which gradually decreased at 16 th week. They also found higher amount of CO_2 evolution when soils were treated with 1 percent straw and kept at 60 percent maximum water holding capacity. It was also noted that when soil was in cubated with easily decomposable carbohydrates like glucose. large amount of CO_2 gas was evolved at 60 per cent maximum water holding capacity.

The soil inorganic carbon (SIC) stock of black cotton soils (BCS) of Maharashtra has been found to 0.01 percent of total SIC stock of the Indian soils in first 30 cm depth of soils (Bhattacharyya *et al.,* 2001a). Black soils of the Deccan region have been reported as neutral to very strongly alkaline in reaction (pH 7.1 to 9.3), and poor to rich in organic carbon (0.3 to 1.36 per cent) (Murthy *et al.,* 1982., Varade *et al.,* 1985., Pal and Deshpande, 1987b). Many researchers reported < 1 per cent organic matter in black soils of Maharashtra in India (Magar, 1990., Nimkar, 1990., Balpande *et al.,* 1996., Padole *et al.,* 1998). The soil organic carbon (SOC) stock for BCS of Maharashtra accounts for only 0.008 percent of the total SOC stock of entire country (Bhattacharyya *et al.,* 2001a).

Ghuge (2002) evaluated the fertility status of sugarcane growing soils of area under Balaghat Shetkari Co-operative Sugar factory, Ujana. He reported that the bulk density of soil ranged from 1.18 to 1.52 g cm^{-3}. With a main value of 1.35 g cm^{-3} with an average porosity 48.97 per cent. The soil pH range from 7.6 to 8.5, electrical conductivity varied from 0.17 to 0.48 dSm^{-1} the $CaCO_3$ Content of these soils ranged between 3 to 26 per cent the organic carbon content in Vertisols of the area ranged from 0.40 to 1.01 per cent.

Kadao *et al.* (2003) observed that the eight typical pedon sites were selected in banana growing soils of Wardha district of Maharashtra. The CEC ranged from 8 to 73 cmol (P^+) kg^{-1} in different horizons and it was directly dependent on clay content. Patil and Meisheri (2004) reported that soil of Konkan region. The sixty two surface (0-15 cm) soil samples were analyzed the cation exchange capacity varied from 15.74 to 46.52 (cmol (p^+) kg^{-1}). Dhale and Jagadish Prasad (2009) reported that the soils of Jalna district of Maharashtra. The CEC ranged from 38.8 to 67.8 cmol (P^+) kg^{-1} in different horizons. The higher CEC and CEC/clay ratio indicate that these soils are dominated by smectites.

Padole and Mahajan (2003) studied the swell-shrink soils of Vidharbha region and recorded the calcium carbonate content of these soils between 1.3 to 15.6 per cent. Further, low values of calcium carbonate were noticed from 0.25 to 1.75 and 0.75 to 4.25 per cent in very high rainfall lateritic and non lateritic soils of Konkan region, respectively (Patil and Meisheri, 2004). Meena *et al.* (2006) studied on macro and micro nutrients in some soils of Tonk district of Rajasthan and reported calcium carbonate between 0.20 to 10.10 per cent.

Chaudhary and Shukla (2004) analyzed one hundred and forty surface soil samples from seven established soil great groups of arid region of Western Rajastan and reported that the soil pH of these soil were ranged from 7.66 to 9.60. Vaidya and Mali (2008) reported that the soils of kini farm College of Agriculture Osmanabad are low to moderate in organic carbon, neutral to alkaline (6.8 to 7.2) in reaction and calcareous in nature (<5%).

Sahrawat *et al.* (2005) samples of surface (0–30 cm) soils were collected from eight sites in the semi-arid tropical regions of India to evaluate and compare the long-term effects of lowland rice or paddy and non-rice or arable systems on soil organic C (SOC), soil inorganic C (SIC) and total N status. The results showed that soil samples from sites under lowland rice double cropping system had greater organic C and total N content than those from soils under rice in rotation with upland crop or under other arable systems. The SOC:N ratio was wider in soil samples from sites under lowland rice compared to those under other arable systems, which had lower C:N ratios. Samples from soils under lowland rice system tended to have a narrower SIC:N ratio than those under arable systems, indicating a better pedoenvironment under paddy rice. Our results support earlier findings that sites under continuous wetland rice cropping accumulate organic matter and contain higher soil organic matter compared to the sites under other arable systems.

Naidu *et al.* (2006) evaluated the suitability of soils for growing grape by matching the land use requirement of grape with land characteristics of study area. Soil producing chloratic plants showed lower values for pore space and volume of soil air and the difference increased with increasing depth. The CO_2 concentration was higher, resulting in lower oxidation-reduction potential and increased solubility of $CaCO_3$.

The soil organic matter plays a very important role in maintenance and improvement of soil properties as well as nutrient status of soil. In addition to this, it also improves soil structure, infiltration rate, hydraulic conductivity, water and nutrient storage capacity and reduces soil erosion (Smith and Elliott 1990). Kalbhor (2007) observed that, soils of Marathwada Agriculture University, Parbhani were some variation recorded which ranged between 5.6 to 8.7 g kg^{-1}. The higher organic carbon is due to the virginity or heavy application of fertilizers in the soil. Also it is due to recyding of organic residues. The soil variation was found from medium to high. The organic carbon content of soil varied from 0.2 to 0.8 per cent. It was observed that as depth increases per cent organic carbon decreased. Soils were low to moderate in organic carbon content. The organic carbon content is very low in near to murrum layer as compared to the overlying horizons (Patil, 2010).

Kundu *et al.* (2008) stated that, the relationship between addition of organic C and storage under rained long term (27 years) soybean – wheat cropping in a sandy low soil of sub-temperate agro ecosystem of north west Himalayas. The combination of organic N,P and K (NP, NK and NPK) along with N+FYM. Fertilizers and FYM were applied annually to soybean crop only following different treatment combinations. The average annual contribution of C input from soybean and wheat was 30.3 % and 30.1 %, respectively of the harvestable above group biomass. The annual gross C inputs to soil were found to be 1097 kg C ha^{-1} under control plots and 5201 kg C ha^{-1} under NPK + FYM treated plots . The annual rate of total soil organic carbon (SOC) enrichments ranged from 84.3 to 964.3 kg C ha^{-1} in 0-45 cm soil layer.

Dhale and Prasad (2009) reported that the soils of Jalna district of Maharashtra. The surface horizons of P1 to P4 had organic carbon > 6.0 g kg ha^{-1}

but it was not so in other pedons. Which indicates that organic carbon was lower in pedons having higher pH and $CaCO_3$. Thakare and Ingle (2010) the organic carbon content of the soils of Jalgaon district varied from 0.21 to 0.81 per cent which could be rated as very low to moderately high. The contents also decreased with an increase depth from surface to surface layers.

Dhale and Jadish Prasad (2009) reported that the soils of Jalna district of Maharashtra. The surface and sub-surface horizons of pedons P1 to P4 had $CaCO_3$ ranging from 35.3 to 68.8 g kg^{-1}. Whereas, saprolite layers had calcium carbonate to the tune of 200.3 to 247.1 g kg^{-1}. In general, $CaCO_3$ varied from 79.8 to 126.1 g kg^{-1} in P5, P6 and P7 and tended to increase with depth barring last horizon of P7.

Dhale and Prasad (2009) studied that the soils of Jalna district of Maharashtra and reported the available nitrogen ranged from 68 to 313 kg ha^{-1}, respectively in different horizons and in general, their content exhibited a decrease with depth. Thakare and Ingle (2010) analyzed the soils of Jalgaon of Maharashtra reported the available nitrogen content of soils ranging 94 to 358 kg^{-1} i.e. soils had very low to moderate.

Srinivasarao *et al.* (2009) stated that, soil carbon (C) pools play a crucial role in the soil's quality, availability of plant nutrients, environmental functions, and global (C) cycle. Dry lands generally have poor fertility and little organic matter and hence are candidates for C sequestration. Carbon storage in the soil profile not only improves fertility but also abates global warming. Several soils, production, and management factors influence C sequestration, and it is important to identify production and management factors that enhance C sequestrations in dry land soils. The order Vertisols, Inceptisols, Alfisols, and Aridisols. Inorganic C and total C stocks were larger in Vertisols than in other soil types. Soil organic C stocks decreased with depth in the profile, whereas inorganic C stocks increased with depth. Among the production systems, soybean, maize, and groundnut-based systems showed greater organic C stocks than other production systems. However, the greatest contribution of organic C to total C stock was under upland rice system. Organic C stocks in the surface layer of the soils increased with rainfall (r 50.59*), whereas inorganic C stocks in soils were found in the regions with less than 550 mm annual rainfall. Cation exchange capacity had better correlation with organic C stocks than clay content in soils.

Results suggest that Indian dry land soils are low in organic C but have potential to sequester.

Srinivasarao *et al.* (2009) observed that, Vertisols and associated soil had relatively greater SOC stocks than other soil types, where as soils of regions with less rainfall showed large organic C content than soils of reations with more rainfall. Among of rainfall was significantly related with amounts of organic C stocks in the soil, and legume-based production systems showed more organic C sequestration. As soils of India are very low in organic C, it's depletion occurs at a rapid rate because of continuous cultivation and exposure of the sub-soil organic matter. However, long-term manaure experiments under rainfed conditions showed marginal improvement in organic C levels with regular addition of organic matter.

Patil (2010) reported that the cation exchange capacity of Entisols, Lithic Ustorthents (P1, P4 and P9) ranged from 22.46 to 27.41 $mmol^{-1}$. Highest CEC was observed in Typic Haplusterts (34.39 to 44.08 $mmol^{-1}$) as compared to Typic Ustochrepts (20.23 to 32.97 $mmol^{-1}$). The high CEC is attributed to the high amount of clay. The high cation exchange capacity of these black soils is attributed to its semectitic clay mineralogy (Pal and Deshpande, 1987). Since the soils under study have low to moderate organic carbon status. Clay fraction appears to influence largely the cation exchange capacity values. The cation exchange capacity is the charge behavior of soils, whereas clay is the fundamental block contributing towards its cation exchanges, its relationship with clay rather than toposequential placement of the soils is appropriate (Ram and Gaikwad, 1985). Moreover the relationship of cation exchange capacity (CEC) with crop yield suggested that the yield of crop was influenced by the CEC of soil and it was positively correlated between CEC of soil and yield of soybean ($r = 0.751$) and pigeon pea ($r = 0.759$). The CEC increases the yield of soybean and pigeon pea increased.

Likhar and Jagdish Prasad (2011) studied that the soils of orange growing in Nagpur district of Maharashtra. The ranging of available nitrogen from 50.2 to 250.9, respectively in different pedons and in general, their content decreased with the depth.

Agarkar *et al.* (2012) studied on characterization of some cotton growing soils of Wardha district of Vidharbha region of Maharashtra. The calcium carbonate content from 3.96 % (P2) to 14.19 % (P6). The higher calcium carbonate in soil affected the water holding capacity of soil which has great bearing on crop production under rainfed condition.

Selvaraj and Naidu (2012) reported that soil of Chittoor district in Andhra Pradesh. The organic carbon content in soils varied from 1.1 to 5.2 g kg^{-1} (uplands) and 0.4 to 6.0 g kg^{-1} (plains) Selvaraj and Naidu (2012) studied that classification and evaluation of soils of Chittor district in Andhra Pradesh. The available nitrogen in surface soil samples varied from 215 to 676 kg ha^{-1} through out of the depth. However, available nitrogen content was found to be maximum in surface horizons and decreased with depth which is due to decreasing trend of organic carbon with depth. Similarly, the soils of Vadamalalpeta Mandal of Chittoor district, Andhra Pradesh. The available nitrogen varied from 108 to 291 kg ha^{-1} throughout the depth.

2.3.1 C:N, C:P, C:S, ratio and its influence on soil properties.

Bharambe and Ballal (1976) showed that, literate soils of Maharashtra vary in the range of 8.21 to 12.8 and 15.3 to 23.8 C: N and C: P ratios, respectively. Ghatol (1972) reported C: N and C: P ratio from 5.20 to 17.9 and 5.4 to 12.4, respectively in soils of Marathwada. Patil and Sonar (1994) studied C: N and C: P ratio of various agro climatic zones of Maharashtra and indicated range of ratio between 7.2 and 14.1 and 5.5 and 7.9 in soils of Maharashtra, respectively.

Ghatol and Malewar (1978) showed that the cultivated soils of Maharashtra varied in C: N and C: P ratios, considerably. The extremely low C: N and C: P ratios were indicative of fact that low content of organic matter has undergone required degree of oxidation and thereby decreasing ratio of C:N and C:P ratio form vary from vary desiccated humus, while extremely higher C:N and C:P revealed that organic matter appeared to be more immobilized form of N and P.

Balgopalan and Jose (1983) observed in forest soils of Kerala relatively higher total N and the C:N ratio was in the narrow range of 6.68 to 7.01 except upland literate soil where wide range of C:N ratio was found 4.17 to 25.44. Usha and Jose (1984) while studying characterization of organic matter in literate zones of Kerala established relationship between elemental dconstituent of soil organic matter and noticed C: N ratio 15.04 to 7.29 with mean value of 8.71 in the same soil. Dkhar *et al.*, (1986) Studied characterization of humic acid and folic acids of forest and cultivated soils. They reported the elemental composition of humic acid and fulvic acid and ratio of C:N in order to elucidate the stochiometric relationship among these elements. Carbon and nitrogen contents of humic acid in surface soils were higher than those in subsurface soils but reverse was the case with fulvic acids. There was no marked variation in elemental composition of humus of forest and cultivated soils.

The C:N and C:P ratios are the indices of characterization of soil organic matter showing the degree of decomposition of organic material also magnitude of decay stabilization with other soil components. In surface soils C:N and C:P ratio varied from 4.48 to 25.44 and 4.20 to 35.71 inducting wide variation in these parameters in soils of peninsular India (Malewar *et al.*, 1989).

Surekha and Rao (2009) reported that influence of organic source in combination with chemical fertilizers on productivity and Soil quality in irrigated rice-rice system. The residues effect of organics was observe after two years of application. Organic sources improved the soil physical (bulk density and penetration resistence), fertility (soil organic carbon and available N and K) and biological (soil respiration) parameters over in organic fertilizer alone green gram with moderate C:N ratio and high ligin content (green gram) perform better then wide as strow and narrow (dhaincha) C:N ratio sources with low lignin content.

2.4 Effect of various factors on soil organic carbon and nutrient status

Chavan *et al.* (1980) observed significant negative correlation of free$CaCo_3$ with available Zn and Mn. Similarly, Patil and Singte (1982) also showed that available Fe, Mn and Zn were significantly negatively correlated with calcium carbonate. Thakur and Bhandari (1986) recorded that available P showed significant and positive relationship with $CaCO_3$. Whereas Zn and Mn positively correlated with $CaCO_3$ and Cu had significantly and positively related with $CaCO_3$.

Sahu *et al.* (1990) recorded that pH had negative correlation with DTPA extractable micronutrients. Similarly, Tiwary and Mishra (1990) also observed that the available Zn and Mn were negatively correlated with soil pH. Murthy and Srivastava (1994) also indicated that both available Zn and Mn were negatively related to soil pH. They further recorded that both Zn and Mn have lower values of stability constant with soil humic substances and hence their solubility was more affected by pH increase. Further, Datta and Munna Ram (1993) observed that the available Zn and Cu had significant and negative correlation with pH in upland soils. Patil and Sonar (1994) also showed that DTPA extractable Mn had negative relationship with pH.

The available Fe, Mn, Zn and Cu had positive correlation with organic carbon (Tiwary and Mishra, 1990). Saha *et al.* (1996) also showed that the extractable Cu and Zn content of the soils had significant positive correlation with organic carbon content of the soils. Further they have reported that high content of Zn and Cu in soil organic matter was the reason for such relationship. Datta and Munnaram (1993) observed that the available Cu and Fe were positively correlated with organic carbon, whereas available Zn had negative correlation with organic carbon in upland and lowland soils.

Alok Kumar and Yadav (1993) conducted a long term field experiment on inceptisols of Faijabad and reported that no marked effect on soil pH under continuous rotation cropping with chemical fertilizers. Similar trend of observations were reported by Bhardwaj *et al.* (1994) under long term rotational cropping with chemical fertilization.

Murthy and Shrivastav (1994) recorded that available K and Fe showed positive relationship with organic carbon content. Patil and Sonar (1994) showed positive relationship between DTPA Zn and organic carbon.

More (1994) conducted a field experiment from 1987 to 1990 on typic chromustert at Marathwada Agricultural University Farm, Parbhani. The different treatment were tried, which consisting of (T1) press mud cake 20 tonnes ha^{-1}, (T2) dried biogas slurry 10 tonne ha^{-1} + press mud 20 tonne ha^{-1}, (T5) wheat straw 10 tonne ha^{-1} + FYM 25 tonne ha^{-1}, (T6) FYM 25 tonnes ha^{-1} + press mud 20 tonne ha^{-1}, (T0) control under rice wheat sequence cropping. The study indicated that the addition of farm waste and organic manures to sodic soil had beneficial effect on the nutrient availability. All the treatments resulted in increasing the availability of nitrogen content over the control. FYM @ 50 tonnes ha^{-1} showed highest available nitrogen (385 kg ha^{-1}) which could be due to the addition of organic materials in soil.

Patil and Sonar (1994) reported that DTPA Mn had negative relationship with $CaCO_3$. Similarly, Nipunage *et al.* (1996) also recorded that available Mn and Fe had negative correlation with $CaCO_3$.

Sitaula *et al.*, (1995) observed that soil pH has a marked effect on the growth and proliferation of soil microbes. In soil with pH 3.0, 2 to 12 fold less

CO_2 efflux has been observed than the soil at pH 4.0. Shuman (1999) conducted field experiment on fine and coarse soil and the soils were amended with commercial compost, spent mushroom compost, poultry litter, cotton gin litter, industrial secondary sewage sludge and commercial humic acid. The study indicated that organic amendment have profound influence on soil properties most of which were beneficial to both plant growth and to the encouragement of soil micro flora and fauna.

P, K and Fe showed positive correlation with EC of soil (Murthy *et al.*, 1994). While, Nipunage *et al.* (1996) revealed that EC had significant negative correlation with available Mn and Zn. DTPA extractable Zn also showed significant and positive correlation with EC (Pharande *et al.*, 1996).

Nipunage *et al.* (1996) revealed that the soil pH showed significant negative correlation with available Mn and Zn. While, Pharande *et al.* (1996) reported significant and positive correlation of DTPA extractable Zn with soil pH. Sharma *et al.* (2003) observed that the Zn, Cu, Fe and Mn were negatively correlated with soil pH. Similar significant negative correlation between soil pH and available Cu was recorded by Meena *et al.* (2006).

DTPA extractable Zn had significant positive correlation with organic carbon (Pharande *et al.* (1996). The organic carbon was significantly and positively influenced the DTPA extractable Zn, Cu and Fe content in soil (Murthy *et al.*, 1997). Patil *et al.* (2003) showed that the DTPA Zn had positively correlated with organic carbon. Sharma *et al.* (2003) found that the available Zn, Cu, Fe and Mn were significantly and positively correlated with organic carbon. Meena *et al.* (2006) showed that available Fe and Cu had positive correlation with organic carbon.

Hagedorn *et al.*, (1997) studied the application of organic fertilizer has a strong influence on N availability, but the effect can be negated by heavy rainfall. Incorporation of farmyard manure (7 tonne ha^{-1}) was small, whereas the farmyard manure was found to mobilize N after a period of N immobilization. Incorporation of sorghum residues had only a small effect, while mixing the straw with green and farmyard manure immobilized N temporarily.

Bellakki and Badanur (1997) conducted a long term field experiment on rabbi sorghum-safflower rotational cropping in Vertisol at Bijapur under dry land condition and reported that, the organic carbon content of surface and subsurface soil increased significantly due to incorporation of FYM or sunheamp either alone or in combination with fertilizers as compared with recommended dose of fertilizer. This could be attributed to addition of organic material and also due to better root growth and more plant residues addition after harvest of the crop.

Patil *et al.* (1999) studied the effect after long term manuring and fertilization to sorghum-wheat cropping system in Vertisol. The study indicated that, the various nitrogen supplying organic materials increased organic carbon content of soil and rated as FYM > wheat straw > green leaf manures. Maximum organic carbon built up was observed when 50 per cent NPK through inorganic fertilizers plus 50 per cent N through FYM were applied.

Gupta *et al.*, (1999) studied that the ammonical nitrogen increase the interaction up to 20 to 30 days of incubation and thereafter, the drastic reduction was observed. This might be attributed to the completion of process in soil by organism and the least availability of substrate for ammonification. Similarly, the enzymatic oxidation of ammonia to nitrate was started by the organism in the soil. Further the decrease in soil pH might have help in reducing loss of ammonia through volatilization.

Hegde (1999) integrated nutrient supply of inorganic and organic sources is of great importance for maintenance of productivity in intensive cropping systems. The integrated use of chemical fertilizers and the organic sources of farm yard manure (FYM), wheat straw, and green manure on the long-term productivity of an irrigated sorghum (*Sorghum bicolor* (L.) Moench)-wheat (*Triticum aestivum* (L.) emend. Fiori & Paol) system at three semiarid sites. The results showed the possibility of substituting 50% of the N requirement for sorghum by FYM without adverse effect on productivity. Substitution of N fertilizer by wheat straw and green manure generally reduced yields of both sorghum and wheat. Integrated nutrient supply increased soil organic carbon and available N compared to application of all nutrients through fertilizers. It had a variable effect on available P status and reduced the decline in available K. Available soil S, Mn, and Fe increased, while available Cu and Zn remained unaffected. Because the integrated nutrient supply increased soil fertility, it is suggested for use in an irrigated sorghum-wheat system in order to maintain soil productivity.

Gupta *et al.* (2000) reported that, the increase in organic carbon status was directly related with added quantity of urea and manures. Available 'N' status increased with increase in 'N' addition. Combined application of urea and FYM significantly enhanced organic carbon and available 'N' status over similar 'N' addition through urea alone.

Cooperband (2000) assessed the maturity of sawdust based composting and observed that all compost maintained a high respiration rate during first 60 days of composting. NH_4-N declined within the first 60 day of composting indicating microbial immobilization of mineral nitrogen during the active phase of composting. Production of high NO_3-N were good predictor of compost stability, maturity of compost resistance to change, while dissolve organic carbon, C:N ratio and electrical conductivity (EC) were not.

Tiwari *et al.* (2000) studied field experiment on sandy loam soil (Ustrochrept) at CSAUAT, Kanpur on wheat-green gram cropping sequence. The wheat straw nodes plus biogas slurry in conjunction with nitrogenous fertilizers @ of 5o kg ha^{-1} showed improvement in organic carbon content of soil. The effect was significant by 7.5 tonne ha^{-1} of wheat straw nodes plus biogas slurry only.

Mishra *et al.*, (2001) reported that, the carbon content of the wheat straw decreased rapidly during first two weeks and there after a gradual decrease in the C content of the wheat straw continued until end of the 24 weeks. By the end of 22^{nd} week only 26.0 and 25.7 percent carbon remained in the decomposed wheat straw in case of green manuring + green manuring treatments, respectively. Carbon mineralization appeared to be the major mechanism of weight loss during decomposition of the wheat straw, as the pattern of the weight loss of straw and carbon mineralization for the straw was remarkably similar.

Wani *et al.*, (2003) observed that an improved system of catchment management in combination with appropriate cropping practices can sustain increased crop production and improve soil quality of Vertisols, compared with prevailing traditional farming practices. Initiated in 1976, the improved system consisted of integrated land management to conserve soil and water, with excess rainwater being removed in a controlled manner. This was combined with improved crop rotation (legume based) and integrated nutrient management. In the traditional system, sorghum or chickpea was grown in the post-rainy season with organic fertilizers, and in the rainy season the field was maintained as a cultivated fallow. The average grain yield of the improved system over 24 years was 4.7 t ha^{-1} yr^{-1}, nearly a five-fold increase over the traditional system (about 1 t ha^{-1} yr^{-1}). There was also evidence of increased organic C, total N and P, available N, P and K, microbial biomass C and N in the soil of the improved system. A positive relationship between soil available P and soil organic C suggested that application of P to Vertisols increased carbon sequestration by 7.4 t C ha^{-1} and, in turn, the productivity of the legume-based system, thus ultimately enhancing soil quality.

Krishna *et al.* (2004) observed that, rice crop occupies a major share of total arable land. The recycling of its residues has the great potential to return a considerable amount of plant nutrients to the soil in the rice based crop production systems. Particularly the rice-wheat cropping system is the most intensive production system in the country. The yield stagnation consequent upon the declining soil organic carbon is a major threat to this system. Therefore it is a great challenge to the agriculturists to manage rice residues effectively and efficiently for enhancing sequestration of carbon and maintaining the sustainability of production.

Krishna *et al.* (2004) conducted that, the rice residues are important natural resources, and recycling of these residues improves the soil physical, chemical and biological properties. Management of rice straw is a major challenge as it is considered to be a poor feed for the animals due to high silica content. The potential of rice residues and its management options, residue effects on soil properties and crop productivity. On the basis of reported research results by different researchers, an analysis has been made. A rice-wheat sequence that yields 7 t ha^{-1} of rice and 4 t ha^{-1} of wheat removes more than N 300, P 30 and K 300 kg ha^{-1} from the soil; the residues of rice and wheat amount to as much as 7-10 t ha^{-1} yr^{-1}.

Ghuman and Sur (2006) reported that, the soil bulk density, infiltration rate, soil moicher storage, soil pH and organic carbon content were affected by organic manuring during 4 to 6 seasons, manuring significantly increased wheat grain yields over that of control. During the remaining two seasons, again yield increase was no significant wheat responded to fertilizers N. manuring the yield with FYM either at 6 or 18 t ha^{-1}. During summer seasons and taking a pearl millet fodder seemed to be a profitable practice rather than keeping the soil fallow and then taking that crop during winter season.

2.5 Soil site suitability for different crops

Walkar *et al.* (1968) reported that landform parameter such as slope, length and direction, distance from the hill slope summit and its relative elevation influence the soil profile development. They also observed the influence the slope, length and its direction on horizon development.

The FAO sponsored a series of expert consultations on land evaluation in the early 1970. These resulted in the landmark framework for land evaluation published in 1976 (FAO, 1976).

The principal objectives of the land evaluation is to select the optimum land use for each defined land unit taking into account both physical and socio-economic consideration and the conservation of environmental resources for suitable use (FAO, 1983). The FAO framework provides a set of principles from which land evaluation can be established keeping into account the local conditions. For the land use specific evaluation the comprehensive system of land suitability evaluation has been suggested by Sys (1985) and Sys *et al.* (1991). The evaluation is carried out by comparing the land characteristics with the limitations levels of the requirement tables. One single limitation level is attributed to each characteristic and the suitability class is determined by the number and intensity of the limitations. Such evaluation is the basic for the interpretation of soil in term of their suitability for optimum land use planning.

Vadivelu (1983) and Bhattacharyya *et al.* (1989) reported that soil site and climatic characteristics changes with geomorphic unit which is turn influence on land use pattern, They observed that hill ridges with shallow soil were mostly under forest with patches of rain fed crops. The pediments surface with shallow to deep soils were cultivated to sorghum and soybean and pearl millet, while the soils occurring on pediment plain and flood plain's were very deep and cultivated to sorghum, pigeon pea, safflower under rainfed condition.

Kharche (1990) reported that the Vertic Ustochrept and Typic Chromusterts as highly suitable for sorghum and moderately suitable for cotton and pigeon pea in Daongi watershed, near Nagpur soils of lithic Ustochrepts was found moderately suitable for sorghum and pigeon pea and marginally suitable for cotton while Lithic Ustorthents soils were unsuitable for cotton and pigeon pea due to shallow rooting depth but for sorghum it was potentially suitable.

Sehgal (1991) evaluated soil – site suitability for different crops and compared the yields as various levels of management, the crop like cotton, pigeon pea sorghum and wheat gave higher returns when grown on the lower plains having Typic Chromusterts as dominants soils. However the crops such as groundnut, soybean, and black gram gave maximum yield in Typic Ustocherpts on the upper plains.

Wadodkar (1991) recorded marginal productivity of soybean with 4 to 6 q ha^{-1} yield on shallow soil of basaltic area with depth ranging from 16 to 19 cm.

Sehgal (1991) reported that soil depth is an important criteria for land evaluation. Most of the crop produce excellent yield with an effective soil depth of 90 to 100 cm. (Sys, 1985).

There are many diverse evaluation methods resulting from the work of experts of different research fields (natural sciences, agriculture, geography, economics, *etc.*) and therefore, there exist numerous way of expressing evaluation results. The important evaluation methods include that of Stories Index Rating (Storie 1933); USDA Land Capability Classification (Klingebiel and Montgomery, 1961); Requires parametric approach (Requier *et al.* 1970) and land suitability classification (FAO, 1976).

It is being increasingly realized that the purpose specific and area specific interpretation of basic soil and land characteristics are needed to properly evaluate the suitability of land for a verity of demands that are being made on it. This has prompted various workers to develop specific land suitability classification. For instance, NBSS&LUP (1994) has used soil-site suitability criteria that are developed for the commonly grown agricultural crops keeping into account the local factor. Similar attempts have also been carried out elsewhere for the suitability evaluation of tropical crops. The suitability evaluation results in the first place the actual fitness to produce a given crop. In addition, the nature of constraints identified in the evaluation may be helpful to undertake proper management measures in order to boost the agricultural productivity.

The diagnostic parameter used for suitability evaluation from an important part of this kind of exercise. However, the parameters vary from crop to crop in different areas used by various researchers. An attempt has been made in this investigation to consider the most relevant parameter as the diagnostic soil-site conditions. Land suitability evaluation is casrried out for various agricultural crop and the soil related constraints have been identified in each soil unit.

Saxena *et al.* (1997) evaluated the soils of Gondkhairi watershed in Nagpur district Maharashtra for different crop like cotton, pigeon pea, sorghum and soybean and found that the soils of Typic / Lithic Ustorthents subgroup were unsuitable were as Typic Ustochrepts soils were marginally suitable and Vertic Ustochrepts and Typic Haplusterts are highly suitable for these crop.

Balpande *et al.* (2007) reported that severe limitation of ESP and moderate limitation of pH, Soil texture and $CaCO_3$ and soil depth for suitability of grape in Nasik district, Maharashtra

Dhale and Jagdish Prasad, (2009) studied based on variation in physiography, soils and productivity of sweet orange, seven pedons are characterized in Jalna district of Maharashtra for their physical, chemical properties, nutritional status of soil and leaves. In general, sand, silt and clay content ranged from 14.4 to 46.9, 8.1 to 27.3 and 38.1 to 66.3 % in different horizon. Bulk density ranged from 1.29 to 1.96 Mg m^{-3} and increase with depth. The available N, P and K content ranged from 68.1 to 313.2, 0.92 to 27.0 and 195.7 to 1287.2 kg ha^{-1}, respectively in different pedon. On computation of the existing limitations, a new criterion has been proposed, this criterion indicate that all the pedons are moderately suitable.

Ikhe (2009) reported that Entisols soils are currently not suitable, Vertisols soils are marginally suitable were as Inseptisol soils are moderately suitable suitable for grape cultivation in Buldhana district Maharashtra.

Patil (2011) reported that the soil depth, Clay, PAWC, Coarse fragment, soil pH and organic carbon are influence the soil site suitability for pigeon pea and soybean crops in Osmanabad district.

Niranjana *et al.* (2011) studied that characterization, classification and suitability evaluation of banana growing soils in Andhra Pradesh. They found that the pedons on the inter-hill basin are moderately shallow to very deep, very dark grayish brown clay to dark reddish brown , dark red sandy clay loam to clay loam soils. Soils were classified as very fine, calcareous Vertic Haplustepts.

Likhar and Jagdish Prasad (2011) observed that the six pedons were characterized and evaluated in Nagpur district of Maharashtra. These pedons were shallow underlain by saprolite (P3, P4 and P5) and deep soils (P1, P2 and P6). These factors combinedly result in alternate bearing in P1 but P6 fetches good yield due to having higher clay which provides good drainage. The P2 is rated as marginally suitable owing to severe limitation of texture and moderate limitation of slope and drainage. Similarly, P4 and P5 fetches good yield, because of properly managed in terms of integrated nutrient and water management. Pedons 3 and 5 are moderately suitable with moderate limitations of texture and slope.

MATERIAL AND METHODS

Chapter-III

MATERIALS AND METHODS

The present investigation was undertaken with the specific objectives. These are (1) to study the organic carbon content in varied soil series and surface soils of Agro-ecological region of Marathwada, (2) to evaluate the physical, chemical properties and dynamics of nutrient status of Marathwada soils and (3) to findout the relationship between C:N, C:P and C:S ratio and soil properties and (4) to prepare thematic maps of organic carbon status and otherimportant soil properties. These objectives are approached through the data from 22 soil profiles (soil series spread over the Marathwadaregion) and 330 surface soil samples covering the varied agro-ecological regions of Marathwada.

The project "Organic carbon mapping of Agro-ecological zone of Marathwada" constitute phase wise program that includes soil survey, soil profile studies, soil organic carbon mapping and it's relationship with physical and chemical properties.

3.1 Soil survey for evaluation SOC and other soil properties of varied soil series and surface soils of Marathwada region.

3.2 Relationship between C:N, C:P and C:S ratio with soil properties.

3.3 Preparation of maps of SOC of agro-ecological zone of Marathwada.

3.4 Soil site suitability and Land use Planning

To carry out these phase wise program, the material used and methods adopted are described below.

3.1 Soil survey and evaluation of soil organic carbon and other soil properties of various soil series and surface soils of Marathwada region.

To evaluate the soil organic carbon status of surface soils and its vertical description, 330 surface soil samples and 22 soil profiles spread over the agro-ecological region of Marathwada was carried out during the year 2011-2012. South Central part of Maharashtra is popularly known as "Marathwada" lies between $17^0$35' to $20^0$40' North latitude and $74^0$40' to $78^0$15' East longitude.

The area and locations under survey covers eight district of Marathwada consisting Parbhani, Nanded, Hingoli, Jalana, Aurangabad, Beed, Latur and Osmanabad as shown in map (Figure 3.1). Some of the important aspects like location, relief, climate and methodology adopted for the collection of relevant data are described below.

3.1.1 Location, relief and soils of the Marathwada.

Aurangabad District

Aurangabad district is located mainly in Godavari Basin and its some part towards North West of the Tapiriver basin. The district's general down level is towards South and East and North West part comes in the Purna- Godavari river basin. The Aurangabad district spread between 19^0 and 20^0 North longitude and 74^0 to 76^0 east longitude.

Aurangabad district shows concave relief towards south and south east. Most part of the district has excessive relief and hilly topography. Prominent hills are Satpuda, Mahadev, Mahi and Ajantha which comprised of basalt rock with nodular limestone. Soils are predominantly Entisols.

Parbhani District

Parbhani is located at 19° 27'N latitude and 76°78' E longitude. It has an average elevation of 347 metres. In the northeast of district on the boundary of Hingoli district and Parbhani district is extension of Ajanta ranges called Nirmal Hills. The main river in the district is Godavari which flows from Pathri, Manwat, Sonpeth, Gangakhed, Purnatahsils of Parbhani district. Other rivers are Purna and Dudhana which are tributaries of Godavari.

The climate of the Parbhani district is generally, hot except during the south-west monsoon season. Four season could be marked in year. The cool dry season from December to February, followed by the hot dry season from March to May, the southwest monsoon rainy season from June to September and dry season from October to November prevails in the district

Nanded District

Nanded district is situated between 18°15' to 19°55' north latitude and 77°7' to 78°15' east longitude having altitude of 362.24 m. Godavari is the main river in Nanded district.

Nanded is located on border of tropical monsoon and semi-arid. The area experiences very high temperatures in April and May, heavy rains in August and September, and frost in December and January. Most of the rainfall occurs in the monsoon season from June to September. Average annual rainfall is 927.92 mm, which comes under moderately high rainfall zone. The annual maximum temperature ranges between 29.9 to 44.6°C and minimum temperature ranges between 13.9 to 29.8°C.

Osmanabad District

Osmanabad district lies in the southern part of state. It lies on the Deccan plateau, about 600 m above mean sea level. Parts of the Manjra and Ternariver flow through the district. The district located on the east side of the Marathwada region between latitude 17°35' to 18°40' degrees north, latitude 75°16' to 76°40' degrees east longitude.The rainy season starts from mid-June and continues till the end of September. The climate is humid in October and November and dry and cool from mid-November to January. From February to June the climate is dry and becomes increasingly hot. During summer the temperature of Osmanabad district is low compared to other districts of Marathwada region. The average annual rainfall in the district is 730 mm. Temperature Max 42.1°C; Min 8°C.

Beed District

Beed district lies between 18.28° to 19.28° North latitude and 74.54° to 76.57° East longitude. The main mountain range in district is Balaghat range. The Balaghat range has elevation ranging between 600 to 700m from mean sea level approximately. Among the rivers Godavari, Manjra, Sindhfana, Bindusara and Wan etc. Godavari is the main river in district which flows to northern side while Sina is main river inAshtitaluka.

The Beed district comes under semi arid hot and dry climate. Temperature ranges from 31 to 40°C in summer season and in month of May it may be up to 42°C. in winter season it ranges between 10 to 30°C. Average rainfall is 667 mm.

Jalna District

The district has moderately to gently sloping undulated topography. The Northern part of the district is occupied by Ajanta and Satmala hill ranges.

The 95% area of the district falls in the Godavari basin. The river Godavari flows along the southern boundary from West to East direction. The rivers Dudhana, Gulati, Purna are the principal tributaries of river Godavari, which flow through the district.

The major part of the district falls in the Purna sub basin. The river Purna flows from the central part of the district and meets river Godavari in the neighboring district. The river Khelna, and Girja are other important tributaries of river Purna which flow through the district.

The southern part of the district falls in Godavari sub basin. A very small part of the district located North East of the district fall in the Tapi basin. The general slope of the area is towards southeast. The average altitude above mean sea level is 534 Miters. (M.S.L.).

The district has a sub-tropical climate, in which the bulk of rainfall is received from the southwest monsoon, between June to September. The average annual rainfall of the district ranges between 650 to 750 mm. The district often experiences drought with rainfall recording as low as 400 to 450 mm. The rainy season is followed by winter, which last up to February, during which the minimum temperature ranges between 9 to 10°C and maximum temperature ranges between 30 and 31°C. The winter is followed by hot summer, which continues up to June. The maximum day temperature ranges between 42 and 43°C during summer.

Latur District

Latur district is located between 17°52' to 18°50' North latitude and 76°18' to 79°12' East longitude in the Deccan plateau. It has an average elevation of 631 meters above mean sea level.

The district is divided into two regions-the Balaghat plateau and the northeastern region consisting of Ahmadpur and Udgir. The entire district of Latur is situated on the Balaghat plateau, 540 to 638 metres from the mean sea level.

Average rainfall in the district is 600 to 800 mm. This is usually during the monsoon months from July-October. Moderate temperatures are mainly observed here. The rainfall is unpredictable in turn with the Indian monsoon. Summers here begin from early March to July. Summers are dry and hot. The temperature ranges from 24°C. to 39.6°C, though at the peak they may reach 41°C. From November to January, is the winter season. Temperatures at the peak drop to single digits but usually they however around 13.9°C to 21.8°C. Sometimes lowers up to 11°C. January to March are the months with moderate temperatures.

Hingoli District

Hingoli District is situated between 19°43' - 19°72' N latitude and 77°11' - 77°15' E longitude. The district slopes towards south and average elevation is above 457 meters. It is known as southern plateau. The major rivers flowing through the district of Hingoli are the Penganga, Purna and Kayadhu. Hingoli district is covered by basaltic rock.

The climate of the district is sub-tropical, mosoonic type characterized by mild winter and hot summer. The average rainfall of the district is 895mm.

3.1.2 Agro Ecological Zones of Marathwada Region

Agro climatic zone is a land unit in terms of major climate, super-imposed on length of growing period (Moisture availability period) (FAO, 1983) where as Agro-ecological zone is the land unit carved out of agro climatic zone super imposed on land form which act as modifier to climate and length of growing period.

Depending upon the soil, bioclimatic type and physiographic situations, the country has been grouped in to 20 Agro-ecological regions (AER) and 60 agro-eco subregions (AERS). Each agro-eco sub-region has further been classified in to agro-eco unit at district level for developing long term land use strategies. The constraints and potentials with appropriate ameliorative measures have been described for each region for better understanding and adoption for formulating the plans. This will help in minimizing the deterioration of land quality controlled by soil physical conditions, nutrient availability and organic carbon pool.

The Marathwada region of Maharashtra falls under agro-ecological region no. 6 i.e. Deccan Plateau, hot semi-arid eco region (K4D2). It has four Ecological Sub Regions (ESR) as follows.

6.1:South Western Maharashtra and North Karnataka Plateau, hot dry semi-arid ESR with shallow and medium loamy black soils (deep clayey black soil as inclusion), medium to high AWC (Available Water Capacity) and LGC (Length of Grpwing Crop)90-120 days (K4Dd3).

6.2: Central and western Maharashtra plateau and North Karnataka Plateau and North Western Telangana Plateau, hot moist semi-arid ESR with shallow and medium loamy to clayey Black soil (medium land deep clayey Black soils as inclusion), medium to high AWC and LGP 120-150 days (K4Dm4).

6.3: Eastern Maharashtra Plateau, hot moist semi-arid ESR with medium land deep clayey Black soils (shallow loamy to clayey Black soils as inclusion), medium to high AWC and LGP 120-150 days (K5Dm4).

6.4: North Sahyadris and Western Karnataka Plateau, hot dry subhumid ESR (K4Cd5).

3.1.3 Soils and Mineralogy of the region

Nearly 32.5 m ha Marathwada region are medium black soils, 12.1 m ha deep black soils and 12.4 m ha coarse shallow soils. The fertility index with respect to nitrogen is low in Parbhani, Nanded whereas it is medium in Aurangabad, Jalna, Beed, Osmanabad and Latur districts and fertility index with respect to phosphorus is low in almost all the Marathwada region to except some part of Jalna and Beed districts. It is very high for potash in almost all the district of Marathwada.

The soils under study area formed from the weathering of trap rock rich in iron, copper, lime and magnesia. The black soil constitute bulk of iron minerals (hematite, magnetite and limonite) along with augite, chlorite, hornblende, traces of zircon, tourmaline, apatite, feldspar, quartz, muscovite, pyrite and pyroxenes. Malawar and Randhawa (1978) and Maniyar*et al.* (1981) found that montmorillonite was invariably dominant followed by moderate amount of kaolinite and traces of illite. The soils vary both in texture (light to heavy) and depth (very shallow to very deep).

3.1.4 Natural Vegetation and Land Use of the region

The natural vegetation of area comprises of dry deciduous tree species and grasses. The dominant tree species are Neem (*Azadirachraindica*), Babool (*Acacia Arabica*), Tamarind (*Tamarindusindica*), Mango (*Mangiferaindica)*, Ber (*Ziziphusmauritiana*) and Sandal (*Ozgeinaoojeinesaid*).The area is under both dry and irrigated farming under rainfed cultivation sorghum, soybean (*Glycine max L.*), pigeon pea, millets and cotton *(Gassipumherisutum)* are the main crops. Wheat (*Triticumaestivum*) and Sugarcane *(Saccharumofficirarum)* are grown under irrigation.

3.1.5 Selection of site and collection of soil samples

3.1.5.1 Selection of locations for soil profiles studies.

In order to cover the area of identified soil series (Table 3.1) utmost care has been taken to locate the village of identified soil series **(Soil series of Maharashtra**) and excavated the representative soil profile. The details about location of soil profile, name of soil series latitude and longitude, Mean Annual Rainfall (MAR), Mean Annual Temperature (MAT) (^{0}C) and topography etc. are given in Table 3.1.

Table 3.1.Details of location, soil series , MAR (mm), and MAT (^{0}C) and topography

Sr.No.	District	Soil series	Latitude	Longitude	MAR (mm)	MAT (^{0}c)	Topography	Remarks
1	Aurangabad	Vaijapur	19^{0}89”63	74^{0}79”17	515.9	27.2	Inter hilly	No crack
		Aurangabad	19^{0}89’88N	75^{0}28’42	736	26.5	Plateau	2-3 cm crack
2	Nanded	Mandawa	19^{0}54”88	78^{0}63”96	1078.7	28.3	Undulating valley	2-3 cm crack
		Kinwat	19^{0}45”36	77^{0}49”19	1078.5	29.1	Forest valley	Reddish soil
		Hadgaon	19^{0}16”34	77^{0}45”89	905.6	28.3	Plateau	No crack
3	Beed	Beed	18^{0}95”48	75^{0}75”80	699.4	25.15	Plateau	3-5 cm cracks
		Kej	18^{0}74”92	76^{0}06”48	703.4	26.15	Plateau	No crack
		Georai	19^{0}22”03	76^{0}78”19	683.2	26.15	Subdued plateau	No crack
4	Hingoli	Rohadi	19^{0}45”36	75^{0}82”94	977.9	25.6	Subdued plateau	No crack
5	Latur	Amhadpur	18^{0}57”14	77^{0}01”67	887.0	26.7	Plateau	No crack
		LamanTanda	18^{0}82”53	77^{0}06”04	887.0	26.7	Subdued plateau	No crack
		Ausa	18^{0}15”21	76^{0}30”53	697.1	26.7	Subdued plateau	No crack
		Agril. Latur	18^{0}41”96	76^{0}61”85	743.5	26.7	Plateau	1-2 Crack’s
		Babulgaon	19^{0}24”93	75^{0}61”37	743.5	26.7	Plateau	No cracks
6	Osmanabad	Govindpur	18^{0}63”96	76^{0}78”70	736.2	25.8	Subdued Plateau	1-2 cm cracks’ with 40 cm
		Wadgaon	18^{0}28”68	76^{0}09”97	708.4	25.8	Subdued Plateau of inter hill	No cracks
		Ter	18^{0}18”36	76^{0}56”46	708.4	25.8	Subdued plateau	$CaCO_3$ is present
7	Parbhani	Chudawa	19^{0}26”18	76^{0}50”13	868.7	25.8	Plateau	1-2 cm cracks
		Lohagaon	19^{0}10”41	76^{0}47”35	861.6	26.9	Subdued plateau	$CaCO_3$ present
		Dhasadi	19^{0}07”18	76^{0}46”58	861.6	26.9	Subdued plateau	$CaCO_3$ nodules
8	Jalna	Bharaswada	19^{0}52”28	75^{0}69”89	747.9	27.2	Subdued Plateau	3-5 cm cracks
		Ranjani	19^{0}47”15	75^{0}61”89	747.6	27.2	Plateau	No crack

Collection and preparation of soil samples

To work on the outlined objective of project 22 soil profiles from the Marathawada region (Tabel 3.1) were opened. Simultaneously 15 surface soil samples from the adjoining area of the selected soil profile were collected totaling to 330 surface soil samples from 22 profile locations.

Opening of soil profile and collection of soil samples

In all 22 soil profiles as detailed in table 3.1 were exposed from the various suitable locations of 8 districts by digging out up to parent material and horizons in each profile were identified and studied as per the procedure and proforma supplied by NBSS and LUP, Nagpur (Sehgal, 1992).

Soil samples collected from each horizons were processed, labeled and prepared for analysis.

3.1.5.2 Collection of surface soil samples

Three hundred and thirty soil samples were drawn from various locations of eight districts on and around the identified soil series so as to represent the organic carbon status of the area. The soil samples were collected as per the procedure given by Yadav and Khanna (1978).

The soil samples collected with the help of screw auger up to the plough depth i.e. 20 cm. The collected soil samples were mixed thoroughly by hand on clean piece of cloth and about 1.5 kg composite representative sample was retained by quartering the soil.

Processing of soil samples for Analysis

Collected soil samples were dried, pounded in wooden mortar and pistel and were passed through 2 mm sieve. Each sample was thoroughly mixed to make it homogeneous and preserved in properly labeled polythene bag for a laboratory analysis. (For determination of bulk density and free $CaCO_3$, soil samples were retained before pounding the soil).

3.1.6 Analysis of soil Sample

A brief description of standard analytical procedures followed for various physical and chemical characteristics of soil samples are given below.

3.1.6.1 Physical properties

Physical properties of soil were studied in the field and profile description was done as per the procedure suggested by USDA and Soil Survey Staff (1975).

Soil Colour

The soil colour was determined *in situ* by using Munsell and names and Munsellcolour notations from Munsell soil colour chart (Yadav and Khanna, 1979).

Bulk Density of Soil

Bulk density of soil was estimated by Clod method, (Piper,1966).

Particle size distribution analysis

The particle size distribution analysis was carried out as per the international pipette method (Jackson 1979).

Soil Structure

Soil structure was determined by reference to the shape of aggregates for four types designated as platy, prismatic, blocky and granular. (Nikiforoff, 1941).

Hydraulic conductivity

Disturbed soil sample was fully saturated and then leached with distilled water and hydraulic conductivity was determined by constant head method as described by Richards (1954).

3.1.6.2 Chemical Properties

Soil pH

The pH of the soil was measured by pH meter using combined glass electrode pH meter in 1:2.5 soil water suspension (Jackson, 1973).

Electrical Conductivity (EC)

The EC was estimated by the conductivity meter using supernatant liquid obtained from 1:2.5 soil water suspension ratios (Jackson. 1973).

Organic Carbon

Organic carbon was estimated by Wet oxidation method (Walkley and Black's 1934).

Soil Inorganic Carbon (SIC)

Soil Inorganic carbon was determined by using heated dichromate method for TOC as described by (Technical manual U.S.E.P.A, 2001).

Total Carbon (TC).

Total Carbon was determined by sum of using heated dichromate Soil Inorganic Carbon and Soil Organic Carbon.

$CaCO_3$ equivalent

Free calcium carbonate equivalent was determined by rapid titration method (Black, 1965) using 0.5 N HCl.

Cation Exchange Capacity (CEC)

It was calculated by total sum of all adsorbed cations (Jackson, 1979) and soil screened through 2 mm sieve was saturated with 1*N* sodium acetate (pH 8.2). After removal of excess sodium acetate by washing with alcohol, the adsorbed sodium was extracted by washing with 1*N* ammonium acetate (pH 7.0) and the leachate was made upto known volume. Na^+ present in the leachate was determined with a flame emission spectrophotometer (Richards, 1954).

Available Nitrogen

The organic matter in soil is oxidized by $KMNO_4$ in the presence of H_2SO_4. The ammonia formed during oxidation was liberated by adding alkali and absorbed in boric acid to convert ammonia to ammonium borate. Ammonium borate formed was titrated with Std. Sulphuric acid and from H_2SO_4 required for reaction with ammonium borate, the nitrogen was calculated, (Subbiah and Asija, 1956).

Available Phosphorus

The soil was extracted with Olsen's reagent 0.5 M $NaHCO_3$ of pH 8.5 and from the extract available P was estimated colorimetrically as per (Chopra and Kanwar, 1976).

Available Potassium

The available potassium was estimated by extracting the soil with 1 NH_4OAC (pH 7.0) and concentration of K in the extract was measured using Flame photometer (Jackson, 1973).

Exchangeable Calcium and Magnesium

It was determined by using ammonium acetate extract of soil by EDTA, Versenate method (Jackson, 1973).

Available Sulphur

The available sulphur was determined by turbidumetric method by using 1:5 soil and extractant 0.15 % $CaCl_2$ solution on UV spectrophotometer at 340 nm wave lengths (Williams and Steinbergs, 1969).

Available Micronoutrients from Soil:

The micronutrients Fe, Mn, Zn and Cu were determined from the DTPA extract (Lindsay and Norvell, 1978) aspired to Atomic absorption spectrophotometer. Model AA 200 of Perkin Elmer

3.1.6.2.1 Total NutrientAnalysis

Total Nitrogen

It was estimated by Kjeldahl's method as described by Jackson (1973).

Total Phosphorus

For determination of total soil P, 1 gm of soil sample was digested with 20 ml concentrated nitric acid and 10 ml of 60 percent perchloric acid. Phosphorus in solution was determined calorimetrically following vanadomolybdate method as described by Hesse (1971)

Total Sulphur

Total sulphur in soil was determined in diacid digest (Chapman and Pratt, 1961). Total sulphur in all the extracts was determined by turbidimetric procedure of Chesnin and Yein (1951).

Five gm of soil was transferred in 100 ml conical flask and 20 ml of diacid (NHO_3 + perchloric acid) mixture was added to it. By Putting a funnel on the mouth of conical flask the mixture was heated for an hour on hot plate. Then temperature was increased and digested the residue till it became white. Cooled it and filtered in 100 ml volumetric flask. Washed the residue with distilled water until the volume becomes up to the mark. Five ml of aliquot was taken in 25 ml volumetric flask .Then added 1 gm of $BaCl_2$ and shaked well for 1 minute. Added 2 ml of gum acacia solution and volume made up to the mark. Shaked well and taken the turbidity readings within 20 minutes on spectrophotometer at 440 nm wavelength. Developed turbidity of soil extract by taking suitable aliquot (5 ml) and read the intensity of turbidity. Plotted the reading on the standard curve and calculated the concentration of sulphur in the soil material

3.1.6.2.2C:N, C:P, and C:S ratio

C:N, C:P, and C:S ratios were computed by using organic carbon and total Nitrogen, Phosphorus and Sulphur from analysed soil samples data.

3.1.6.3 Biological parameters

Determination of CO_2 evolution from the soil:

CO_2 evolution was determined by the procedure outlined below as described by Pramer and Schmidt (1964). A Known quality (500 g) of fresh soil samples drown from experimental profile were brought to the laboratory and incubated in sealed glass jars by inserting a known but excess quantity of standard alkali (0.1 N NaOH) for 24 hours. After incubation period, the excess quantity of standard alkali which was not required for neutralization of (O_2 was back titrated with standard acid 0.1 N HCl) in presence of 50 % $BaCl_2$ using phenolphthalein as an indicator and calculated the amount of CO_2 evolved by treated and untreated soils. The rate of CO_2 evolution was expressed as mg CO_2 produced per 100 gm soil per 24 hour.

Determination of soil microbial biomass carbon (SMBC)

Soil microbial biomass carbon was determined by using fumigation extraction method as described by (Vance., 1987)

3.2 Relationship between C:N, C:P and C:S ratio with Soil Properties

Organic carbon to total nitrogen and available and organic carbon to total phosphorus and available phosphorus and organic carbon to total sulfur and available sulfur where computed and presented. Further the total carbon to inorganic and organic carbon ratio were developed to find out there contribution on inorganic and organic carbon to total pool of carbon in a soil.

3.3 Preparation of maps of soil organic carbon of Agro-ecological region of Marathwada

The soil organic carbon data encased out from 22 soil profiles and 330 surface soil surface were under for performing on SOC maps. Further the data on Soil Organic Carbon (SOC) were also collected from various agencies and institutes from preparation of maps. The Photoshop software, Microsoft Office was used for performing the maps. The maps are based on the rating and suggested by Parkar (1951).

3.4 Soil site suitability and Land use Planning

The FAO framework on Land Evaluation (FAO 1976) suggests a crop specific suitability system. Further the information on the crops under study have been adopted from the proceeding of the National Meet on soil site suitability criteria for different crops recognized at the National Bureau of Soil Survey and Land Use Planning, Nagpur (NBBS and LUP 1994) and the overall suitability was determined (Sys 1985, Sys *et al.* 1991). The criteria of limitation method as given by Sys *et al.* (1991) is slightly modified because of the increased number of parameter in the present study for the suitability evaluation .

Class S1 (Highly suitable)	Land unit with nil. or up to 5 slight limitation
Class S2 (Moderately suitable)	Land units with more than 5 slight limitation and / or no more than two severe limitation.
Class S3 (Marginally suitable)	Land unit with more than 4 moderate limitation or/ and no more than two sever limitations.
N1 (Currently not suitable) limitation that can be corrected.	Land unit with more than 2 severe
N2 (Unsuitable)	Land units having very severe limitation that cannot be corrected.

3.5 Statistical Analysis

The statistical analysis, i.e. coefficient of correlation and regression equations between dependent and independent variables were obtained as per Panse and Sukhatme (1985) using statistical package for social science software version 0.20.

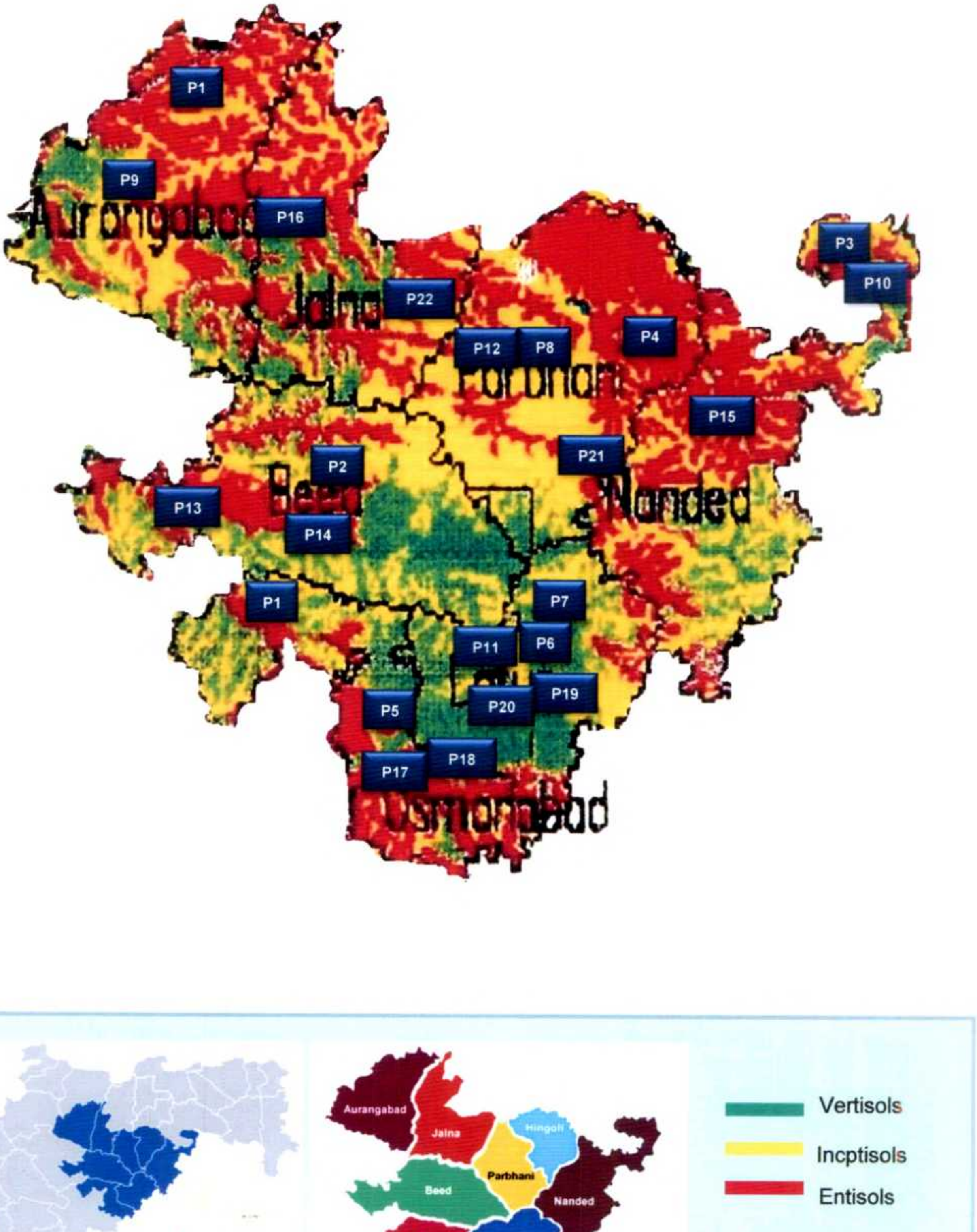


Fig 3.1 : Location map of soil sampling site in Marathwada region.

RESULTS AND DISCUSSION

Chapter-IV

RESULTS AND DISCUSSION

Soils of the Marathwada region were studied for organic carbon, nutrient dynamics and relationship with soil properties with respect to land use in various agro-ecological sub regions.

The result of the field and laboratory investigations carried out on soil samples collected from identified soil series from the Marathwada region have been presented and discussed in this chapter under the following headings.

4.1 Soil survey, classification and morphological, physical and chemical properties of soil

4.2 Soil carbon parameters and ratios

4.3 Soil organic carbon mapping of Marathwada.

4.4 Soil site suitability and land use planning.

4.1 SOIL SURVEY, CLASSIFICATION AND MORPHOLOGICAL, PHYSICAL AND CHEMICAL PROPERTIES OF SOIL

4.1.1 Soil survey and classification.

A broad survey comprising study of 22 soil profiles spread over the Marathwada region was conducted during 2010-11 (Fig. 4.1). Map of Marathwada showing various locations of soil samples collected and simultaneously 330 surface soil samples from adjoining areas of soil profiles were collected. The horizon wise soil samples collected from 22 soil profile and 330 surface soil samples were evaluated for physical and chemical properties. The results emerged out were tabulated, presented, interpreted and discussed under appropriate headings.

Details of soil profile studies

The 22 soil profiles spared over the Marathwada region were grouped as per Agro-ecological zones (Table 4.1). It is observed that out of 22 soil profiles, 13 soil profiles fall into Agro-ecological Zone 6.1 (Drought Prone Zone), 5 in Agro-ecological Zone 6.2 (Assured rain fall zone), 1 in Agro-ecological Zone 6.3 (Moderate high rainfall zone) and three in Agro-ecological Zone 6.4 (Transitionally high rainfall zone). Soil profiles had showed basaltic alluvium parent material (Table 4.1) in 13 pedons, basaltic rock in 8 pedons and weathered basalt in one pedon.

Table 4.1. Soil- site characteristics on Agro-ecological Zone of Marathwada

Sr. No	Agro-ecological Zone and Number	No. of Profile	Pedon	Parent material
1	Agro-ecological Zone 6.1 (Drought Prone zone)	13	Vaijapur-P1	Basaltic alluvium
			Kej- P2	Basaltic alluvium
			Ter-P5	Basaltic alluvium
			Amhadpur-P6	Basaltic alluvium
			Laman Tanda- P7	Basaltic alluvium
			Aurangabad P9	Basaltic alluvium
			Ausa P11	Basaltic alluvium
			Gevrai P13	Basaltic alluvium
			Beed P14	Besaltic rock
			Govindpur P17	Besaltic rock
			Wadgaon P18	Besaltic rock
			Latur P19	Besaltic rock
			Babulgaon P20	Besaltic rock
2	Agro-ecological Zone 6.2 (Assured rainfall zone)	5	Dhasadi- P8	Basaltic alluvium
			Lohagaon P12	Basaltic alluvium
			Bharaswada P16	Besaltic rock
			Chudawa P21	Besaltic rock
			Ranjani P22	Besaltic rock
3	Agro-ecological Zone 6.3 (Moderately higher rainfall zone)	1	Hadgaon- P15	Basaltic alluvium
4	Agro-ecological Zone 6.4 (Transistionally high rainfall zone)	3	Kinwat- P3	Weathered basalt
			Rohadi -P4	Basaltic alluvium
			Mandawa P10	Basaltic alluvium

4.1.2 Distribution of soil profile as per USDA soil survey classification.

The surveyed and studied 22 soil profiles of Marathwada were placed as per USDA classification (Table 4.2). It was observed that out of 22 soil profiles 9 were Vertisols, 5 were Inceptisols and 8 were Entisols.

Table 4.2. Distribution of soil as per USDA soil classification.

Sr. No.	Soil order	Total No of profile	Number of profiles in each soil group
1.	Entisol	8 (36%)	P1,P2,P3,P4,P5,P6,P7,P8
2.	Inceptisol	5 (23%)	P9,P10,P11,P12,P13
3.	Vertisol	9 (41%)	P14, P15,P16,P17,P18,P19,P20,P21,P22

Figure in parenthesis indicates percentage.

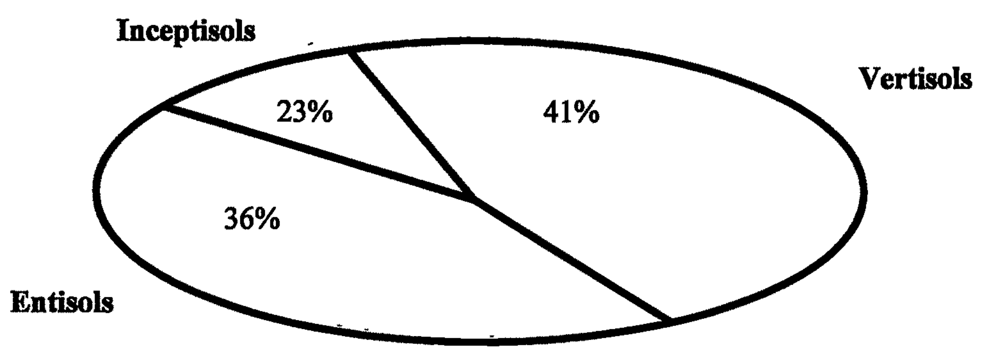


Fig. 4.1 Distribution of soil profiles as per the USDA soil classification.

Figure 4.1 shows the percent distribution of soil profiles as per the USDA soil classification. It was found that 41 percent soil profiles were Vertisols, 36 percent soil profiles were Inceptisols and 23 percent soil profiles were Entisols. The results showed that Marathwada region found to be dominant in Vertisols followed by Inceptisols and Entisols.

The 22 representative soil profiles studied under present investigation were under 6.1, 6.2, 6.3 and 6.4 Agro-ecological sub regions of Maharashtra. These pedons were varied in soil morphology, rainfall attitude, temperature, vegetation, cropping systems, parent material and physic-chemical properties. These soils were classified as par the soil taxonomy (Soil survey staff, 2003). The profile description of these soils is given in Appendix- I, II and III.

Based on field morphology and laboratory characterization the soils on various landforms have been classified and presented in (Table 4.2a). The soils of the study area belonging to three order viz. Entisols, Inceptisols and Vertisols.

4.1.2.1 Entisols

The soil developed on an eroded surface at an elevation of 680 mt MSL in study area (Pedon P_1 to P_8) were lack of diagnostic subsurface horizons. They qualify for the order Entisol and due to presence of Ustic moisture regime, the soils are grouped into Ustorthents. Further in view of Lithic contact within under 50 cm of the surface these soil belong to the subgroup Lithic Ustorthents.

4.1.2.2 Inceptisols

The soils having ochric epipedon under lined by cambic horizon have been classified as ochrept within the order Inceptisols. These soils were located at an elevation 660 mt MSL and back slope (Pedon P_9 to P_{13}). The study area belonging to Ustic moisture regime, these soil qualify for the great group Ustochrepts. At subgroup level these soils classified as Typic Ustochrepts.

4.1.2.1 Vertisols

These soils were deep to very deep, black coloured, clayey (>30%) and characterized by deep and wide cracks, well developed slickenside and pressure faces (Plate 4.8 and 4.10). Thus, these soils were classified under the order Vertisols and the subgroup Typic Haplustert (Table 4.2b) and were observed at an elevation of 640 mt MSL.

Table 4.2a. Classification of the Studied soils of Marathwada (Soil survey staff, 1975)

Entisols pedon P1, 2, 3, 4, 5, 6, 7 and P8,	Vaijapur, Kej, Kinwat, Rohadi, Ter, Ahemadpur, Laman Tanda and Dhasadi	Sandy clay loam, montmorilonitic hyperthermic family of Lithic Ustorthents.
Inceptisols P9, 10, 11, 12, 13	A,bad, Mandawa, Ausa, Lohgaon and Gevrai.	Clayey, mont moriloritic hyperthermic family of Typic Ustochrepts
Vertisols P14, 15, 16, 17, 18, 19,20 and P21	Beed, Hadgaon, Bharaswada, Govindpur, Wadgaon, Latur, Babulgaon, Chudawa and Ranjani.	Very fine, smectitic isothermic family of type Haplusterts.

Table 4.2b. Classification of the Studied soils of Marathwada (Soil survey staff, 2003)

Entisols P1, 2, 3, 4, 5, 6, and P7,	Vaijapur, Kej, Kinwat, Rohadi, Ter, Ahemadpur and Laman Tanda	Sandy clay loam, montmorilonitic hyperthermic family of Lithic Ustorthents.
Inceptisols P9, 10, 11, 12, 13	Aurangabad, Mandawa, Ausa, Lohgaon and Gevrai.	Clayey, montmoriloritic hyperthermic family of Typic Ustochrepts
Vertisols P14, 16, 17, 18, 19,20 and P21	Beed, Bharaswada, Govindpur, Wadgaon, Agril. College, Latur, Babulgaon, Chudawa and Ranjani.	Very fine, smectitic isothermic family of type Haplusterts.
Pedon P8 and P15	a. Hadgaon (Nanded) b. Dhasadi (Parbhani)	a. Very fine, smectitic isothermic family of Sodic Haplusterts. b. Sand clay loam montmorilonitic hyperthermic family of Sodic Ustorthents.

4.1.3 Morphological Properties.

4.1.3.1 Morphological properties of Entisols of Marathwada.

The morphological data of the eight pedons of the Entisols are presented in Table 4.3 and the detail description in Appendix-I. The data indicated that all the pedons are shallow upto 30 cm depth. There were no significant variation in soil colour except Kinwat pedon which is under Transistionally high rainfall zone with forest land use.

Table 4.3. Morphological properties of Entisols of Marathwada

Sr. no	Agro-ecological Zone and Number	Pedon	Horizon	Depth	Matric colour		Structure			SS/PF pressure faces	Soil Consistency	Slope
					Dry	Moist	Size	Grade	Type			
1	6.1 Drought Prone zone	Vaijapur P1	Ap	0-15	10 YR 4/2	10 YR 4/2	m	2	sbk	-	fr, ns, np	3-4
			Ak	15-28	10 YR 4/2	10 YR 4/2	m	2	sbk	-	fr, ns, np	
		Kej P2	Ap	0-15	10 YR 3/3	10 YR 3/2	m	2	sbk	-	s, fr, ns, np	1-3
			C	15-27	10 YR 3/2	10 YR 3/2	m	2	sbk	-	fr, ns, np	
		Ter P5	Ap	0-15	10 YR 3/2	10 YR 3/2	m	2	sbk	-	fr, ns, np	2-3
			Ak	15-20	10 YR 3/2	10 YR 3/2	m	2	sbk	-	fr, ns, np	
		Amhadpur P6	Ap	0-15	10 YR 3/2	10 YR 3/2	m	2	sbk	-	s, fr, ns, np	2-3
			C	15-25	10 YR 3/2	10 YR 3/2	m	2	sbk	-	fr, ns, np	
		L. Tanda P7	Ap	0-15	10 YR 3/2	10 YR 3/2	m	2	sbk	-	fr, ns, np	1-3
			Ak	15-30	10 YR 3/2	10 YR 3/2	m	2	sbk	-	fr, ns, np	
2	6.2 Assured Rainfall Zone	Dhasadi P8	Ap	0-15	10 YR 3/2	10 YR 3/2	m	2	sbk	-	fr, ns, np	1-2
			Ak	15-26	10 YR 3/3	10 YR 3/1	m	2	sbk	-	fr, ns, np	
3	6.4 Transistionally high rainfall zone	Kinwat P3	Ap	0-15	05 YR 4/4	05 YR 5/4	m	2	sbk	-	s, fr, ns, np	5-8
			C	15-20	05 YR 5/4	05 YR 5/4	m	2	sbk	-	fr, ns, np	
		Rohadi P4	Ap	0-15	10 YR 3/3	10 YR 3/4	m	2	sbk	-	fr, ns, np	1-3
			Ak	15-26	10 YR 3/2	10 YR 3/4	m	2	sbk	-	fr, ns, np	

Table 4.4. Morphological properties of Inceptisols of Marathwada

Sr.no	Agro-ecological Zone	Pedon	Horizon	Depth	Matric colour		Structure			SS/PF pressure faces	Soil Consistency	Slop %
					Dry	Moist	Size	Grade	Type			
1	6.1 Drought Prone zone	Aurangabad P9	Ap	0-13	10 YR 3/2	10 YR 3/1	m	2	sbk	-	s, fr, ns, np	1-2
			A	13-25	10 YR 3/2	10 YR 3/1	m	2	sbk	-	s, fr, ns, np	
			Bw	25-65	10 YR 3/2	10 YR 3/1	m	2	sbk	-	fr, ns, np	
		AusaP11	Ap	0-15	10 YR 3/2	10 YR 3/2	m	2	sbk	-	fr, ns, np	1-3
			B	15-30	10 YR 3/2	10 YR 3/2	m	2	sbk	-	fr, ns, np	
			Bw	30-75	10 YR 3/2	10 YR 3/1	m	2	sbk	-	fr, ns, np	
		Gevrai P13	Ap	0-15	10 YR 4/2	10 YR 3/3	m	2	sbk	-	vh, fr, ns, np	3-5
			B	15-25	10 YR 3/2	10 YR 3/3	m	2	sbk	-	fr, ns, np	
			Bw	25-60	10 YR 3/2	10 YR 3/3	m	2	sbk/abk	-	fr, ns, np	
2	6.2 Assured Rainfall Zone	Lohagaon P12	Ap	0-15	10 YR 3/1	10 YR 3/2	m	2	sbk	-	s, fr, ns, np	1-3
			B	15-45	10 YR 3/1	10 YR 3/2	m	2	sbk	-	fr, ns, np	
			Bw	45-75	10 YR 3/1	10 YR 3/2	m	2	sbk	PF	fr, ns, np	
3	6.4 Transistionally high rainfall zone	Mandawa P10	Ap	0-15	10 YR 3/2	10 YR 3/2	m	2	sbk	-	sh, fr, vs, np	1-3
			A	15-45	10 YR 3/2	10 YR 3/2	m	2	sbk	-	fi, vs, vp	
			Bw	45-60	10 YR 3/2	10 YR 3/1	m	2	Sbk/abk	-	vfi, vs, vp	

In typical profile like Kinwat (P-3) of Transistionally high rainfall zone is Yellowish red in colour. The disintegrated weathered murum were present with lime concretions, brown to pale brown in colour, gravelly clay loam texture, with weak sub-angular blocky structure upto 30 cm depth (Table 4.3). The structure of all the pedons were sub angular blocky. The soil consistency varied from soft to slightly hard in dry condition and friable to very friable in most condition and non-sticky and non-plastic in weight condition expect pedon P_3 (Kinwat forest).

Most of the Entisols are cultivated by soybean under protective irrigation. In dry farming conditions *kharif* season crops like sorghum, hulga, bajra are preferably taken up by farmers.

4.1.3.2 Morphological properties of Inceptisols of Marathwada.

The morphological properties of Inceptisols of five pedons are consisting of moderately deep soils (Table 4.4). The detail description of all the five profiles are presented in Appendix-II. These soils were dark grayish brown to very darkish brown in colour. The structure of the pedons were sub angular blocky.

Soil clay was of expanding type of clay mineral when moist and shrinks when dry resulting in development of fine cracks (Pedon 9 and 13). The surface clay material leached out and deposits in sub surface horizons forming textural "B" horizons. Soils are well drained with moderate fertility (Table 4.4 and Pedon 10, 11 and 12). These pedon (Typic Ustochrept) soil consistency varied from slightly hard to hard in dry condition, friable in moist condition slightly sticky, slightly plastic in wet condition.

Most of the Inceptisols are cultivated under irrigation. Such soils are used for wheat, pigeon pea, sugarcane and summer groundnut cultivation.

4.1.3.3 Morphological properties of Vertisols of Marathwada.

The morphology of the Vertisols (Table 4.5) indicated that the soils were deep to very deep (100 cm to more than 120 cm). The cracks were 2 to 10 cm wide at the surface and extended up to a depth of 50 cm. The pressure faces were observed in all the profiles. Slicken sides were well developed and were tilted to an angle 45-60 degree from horizontal. The peds broke into small sub angular blocky to angular blocky peds. The soils were very dark grey to dark yellowish brown (10YR 3/1.5 to 10YR 4/4). The surface horizons of all the pedons generally had sub angular blocky structure and slightly hard to hard (dry) and friable to

Table 4.5. Morphological properties of Vertisols of Marathwada

Sr.no	Agro-ecological Zone	Pedon	Depth (cm)	Horizon	Matric colour		Structure			SS/PF pressure faces	Soil Consistency	Slop %
					Dry	Moist	Size	Grade	Type			
1	6.1 Drought Prone zone	Beed P14	Ap	0-15	10 YR 3/2	10 YR 3/3	m	2	sbk	-	vh, vfi, vs, vp	1-3
			A	15-27	10 YR 3/2	10 YR 3/3	m	2	sbk	-	vh, vfi, vs, vp	-
			Bw	27-60	10 YR 3/2	10 YR 3/1	m	2	sbk	PF	vh, vfi, vs, vp	
			Bssk	60-100	10 YR 3/1	10 YR 3/1	m	2	sbk/abk	SS	vh, vfi, vs, vp	
		GovindpurP17	Ap	0-15	10 YR 3/1	10 YR 3/2	m	2	sbk	-	sh, vfi, vs, vp	2-3
			A	15-30	10 YR 3/1	10 YR 3/1	m	2	Sbk	-	fi, vs, vp	
			Bw	30-60	10 YR 3/1	10 YR 3/1	m	2	sbk	PF	vfi, vs, vp	
			Bssk	60-105	10 YR 3/1	10 YR 3/1	m	2	sbk/abk	SS	vfi, vs, vp	
		Wadgaon P18	Ap	0-15	10 YR 3/3	10 YR 3/3	m	2	Sbk	–	sh, fi, vs, vp	1-3
			A	15-33	10 YR 3/2	10 YR 3/3	m	2	Sbk	–	fi, vs, vp	
			Bss1	33-65	10 YR 3/2	10 YR 3/3	m	2	Sbk	PF	vfi, vs, vp	
			Bssk	65-100	10 YR 3/2	10 YR 3/2	m	2	Sbk	SS	vfi, vs, vp	
		Latur P19	Ap	0-25	10 YR 3/2	10 YR 3/2	m	2	Sbk	–	vh, vfi, vs, vp	1-3
			Bw1	25-60	10 YR 3/2	10 YR 3/2	m	2	Sbk	—	vh, vfi, vs, vp	
			Bw2	60-90	10 YR 3/1	10 YR 3/1	m	2	Sbk	PF	vh, vfi, vs, vp	
			Bssk	90-120	10 YR 3/1	10 YR 3/1	m	2	Sbk	SS	vfi, vs, vp	
		Babulgaon P20	Ap	0-20	10 YR 3/1	10 YR 3/1	m	2	Sbk	–	vh, vfi, vs, vp	1-3
			Bw1	20-45	10 YR 3/1	10 YR 3/1	m	2	Sbk	–	vh, vfi, vs, vp	
			Bw2	25-90	10 YR 3/1	10 YR 3/2	m	2	Sbk	PF	vh, vfi, vs, vp	
			Bssk	90-110	10 YR 3/2	10 YR 3/2	m	2	Sbk	SS	vh, vfi, vs, vp	
2	6.2 Assured Rainfall zone	Bharaswada P16	Ap	0-15	10 YR 3/3	10 YR 3/3	m	2	sbk	-	sh, fi, ns, vp	1-3
			A	15-35	10 YR 3/3	10 YR 3/3	m	2	sbk	-	fi, ns, vp	
			Bw	35-65	10 YR 3/2	10 YR 3/3	m	2	sbk	PF	vfi, vs, vp	
			Bssk	65-102	10 YR 3/2	10 YR 3/2	m	2	sbk/abk	SS	vfi, vs, vp	
		Chudawa P 21	Ap	0-13	10 YR 5/2	10 YR 5/1	m	2	sbk	-	sh, fi, ns, vp	1-2
			B	13-32	10 YR 4/2	10 YR 4/1	m	2	sbk	-	fi, ns, vp	
			Bw	32-68	10 YR 4/2	10 YR 4/2	m	2	sbk	PF	fi, ns, vp	
			Bss	68-100	10 YR 4/2	10 YR 4/2	m	2	sbk/abk	SS	fi, ns, vp	
		Ranjani P22	Ap	0-15	10 YR 3/1	10 YR 3/1	m	2	Sbk	–	vh, vfi, vs, vp	1-3
			Bw1	15-35	10 YR 3/1	10 YR 3/1	m	2	Sbk	–	vh, vfi, vs, vp	
			Bw2	35-70	10 YR 3/1	10 YR 3/2	m	2	Sbk	PF	vh, vfi, vs, vp	
			Bssk	70-105	10 YR 3/2	10 YR 3/2	m	2	Sbk	SS	vfi, vs, vp	
3	6.3 Moderately high rainfall zone	Hadgaon P15	Ap	0-15	10 YR 5/1	10 YR 4/1	m	2	sbk	-	vfi, vs, vp	0-3
			A	15-40	10 YR 4/2	10 YR 4/1	m	2	sbk	-	vfi, vs, vp	
			Bw	40-65	10 YR 4/2	10 YR 4/1	m	2	sbk	PF	fi, vs, vp	
			Bssk	65-105	10 YR 4/2	10 YR 4/2	m	2	sbk/abk	SS	fi, vs, vp	

moderately friable (moist) condition and very sticky and very plastic in wet condition of consistency (Table 4.5). In pedons 14, 17, 18 and 19 the effervescence (with 10% HCl) was slight where as in pedons 15, 16 and 20, it was strong to violent to which attributed process of diffuse powdery from of $CaCO_3$. Calcium carbonate was observed throughout the depth of all soils. The detail interpretation of all pedons of Vertisols are presented in Appendix-III.

4.1.4 Physical Properties

The data on physical characteristics of the Entisols, Inceptisols and Vertisols which have affect the intercultural operation, ultimately affect on the crop growth, so the physical properties of soil need to be considered for various land evaluation are presented in Table 4.6, 4.7 and 4.8 and depicted in Fig. 4.2, 4.3 and 4.4, respectively.

4.1.4.1 Physical properties on Entisols of Marathwada.

The physical characteristics of the Entisols are presented in Table 4.6 and Fig. 4.2. The saturated hydraulic conductivity of soils ranged in between 1.0 to 7.0 cm hr^{-1}. The highest permeability was observed in Kinwat pedon followed by Rohadi of the Transistionally high rainfall area. Under mechanical composition, the sand fraction increased with the depth in the profile P4 (Rohadi) and the sand percentage varied from P8 (Dhasadi) and range from (19.2 to 26.8 per cent). The Saturated hydraulic conductivity noticed in the present study confirms the finding of Vaidya *et al.* (2004). However, silt fraction decreased with the depth of soil profile except P3 (Kinwat) profile, where silt fraction showed increase with depth. The silt content was is between 21.3 to 33.6 percent in these profiles. The clay fractions varied from 40.3 to 58.7 per cent indicating its decrease in depth of all the profiles under all Entisols.

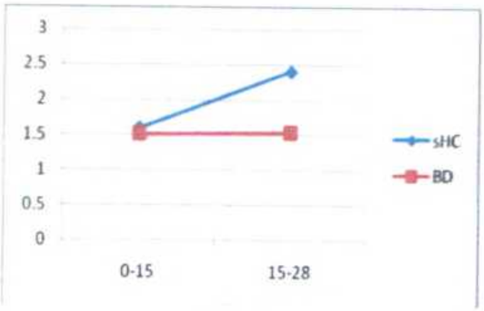
The bulk density ranged from 1.27 to 1.57 Mgm^{-3} indicating its increase with depth of the all profiles. The highest bulk density was observed in Transistionally high rainfall zone. The results noticed in the present study confirm the findings of Waikar *et al.* (2004).

4.1.4.2 Physical properties on Inceptisols of Marathwada.

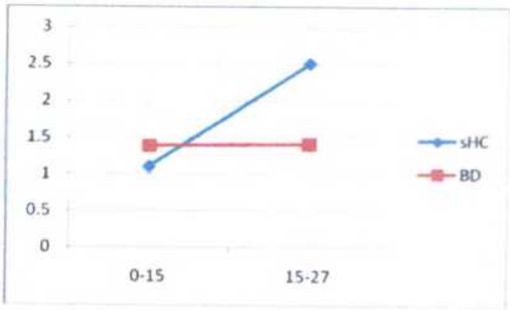
The particle size distribution analysis data presented in Table 4.7 showed that the soils contain 14.8 to 34.3 per cent sand and 17.9 to 33.1 percent of silt. However, silt fraction decreased with the depth of soil profile 10, 11 and 13 except 9 and 12 where silt fraction showed increase with depth. The silt content was in between 14.7 to 33.1 percent in all Inceptisols. The clay fraction varied

Table 4.6. Physical properties of Entisols of Marathwada.

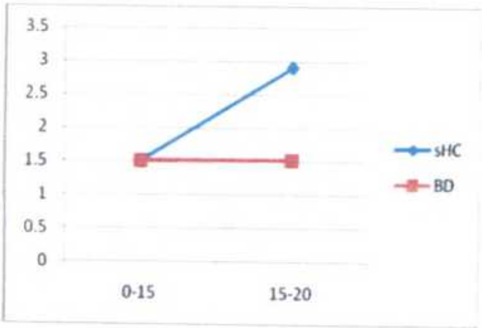
Sr.no	Agro-ecological Zone	Pedon	Horizon	Depth (cm)	SHC (cm hr^{-1})	Bulk density (Mg m^{-3})	Particle size distribution (%) (<2mm)			Textural class
							Sand	Silt	Clay	
1	6.1 Drought Prone zone	Vaijapur P1	Ap	0-15	1.6	1.52	25.9	19.7	54.3	sl
			A	15-28	2.4	1.54	23.6	21.3	55.1	cl
		Kej P2	Ap	0-15	1.1	1.39	19.2	24.7	56.1	sl
			A	15-27	2.5	1.41	19.7	21.6	58.1	sl
		Tar P5	Ap	0-15	1.5	1.51	21.7	28.2	50.1	scl
			Ac	15-20	2.9	1.52	19.6	28.7	51.7	sl
		Amhadpur P6	Ap	0-15	1	1.27	26.1	32.2	43.7	scl
			A	15-25	2.1	1.28	25.6	27.6	46.8	cl
		L. Tanda P7	Ap	0-15	1.3	1.41	22.6	32.8	44.6	sl
			Ac	15-30	2.1	1.39	22.3	30.1	47.8	cl
2	6.2 Assured Rainfall zone	Dhasadi P8	Ap	0-15	3.5	1.39	19.8	30.3	49.9	scl
			Ap	15-26	4.2	1.38	20.5	27.7	51.8	cl
3	6.4 Transistionally high rainfall zone	Kinwat P3	Ap	0-15	7.4	1.57	26.8	32.9	40.3	sl
			C	15-20	7.5	1.53	22.9	33.6	43.7	sl
		Rohadi P4	Ap	0-15	4.4	1.38	21.4	27.4	51.2	cl
			A	15-26	4.5	1.41	25.4	22.7	51.9	cl



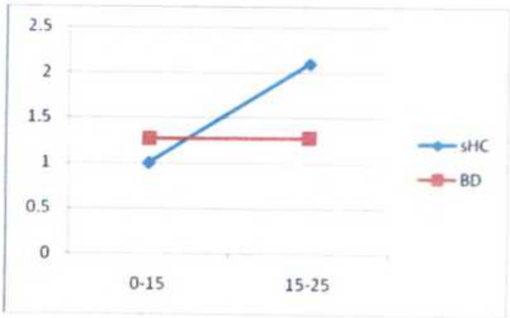
Pedon 1



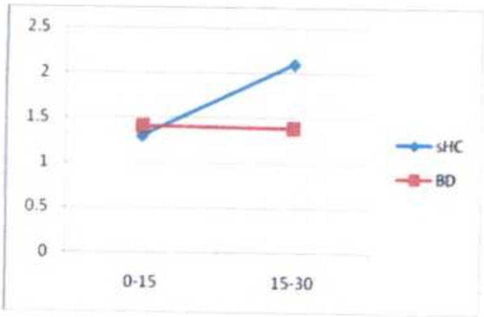
Pedon 2



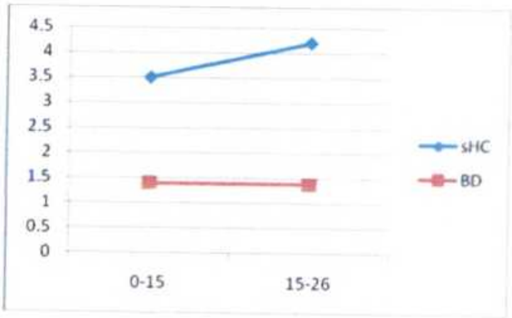
Pedon 5



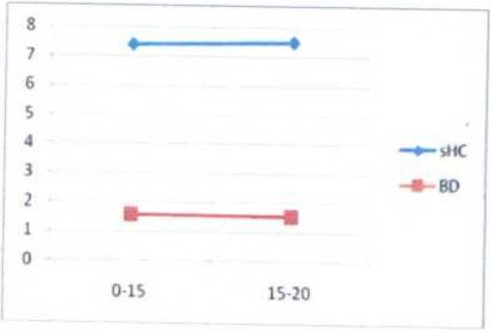
Pedon 6



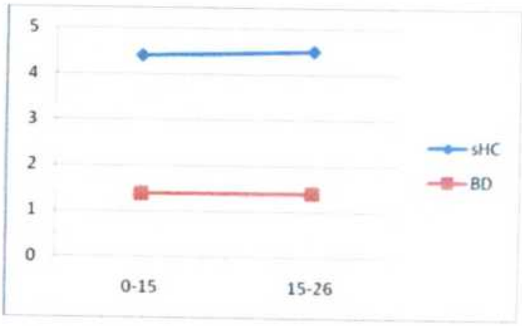
Pedon 7



Pedon 8



Pedon 3

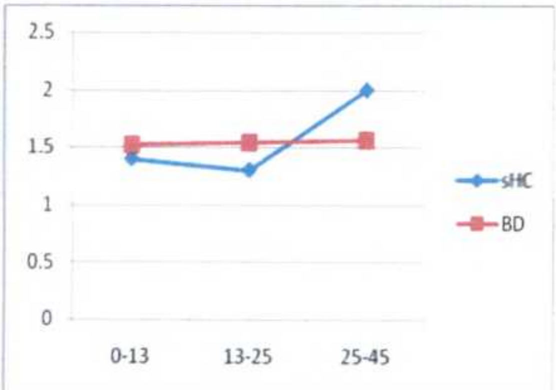


Pedon 4

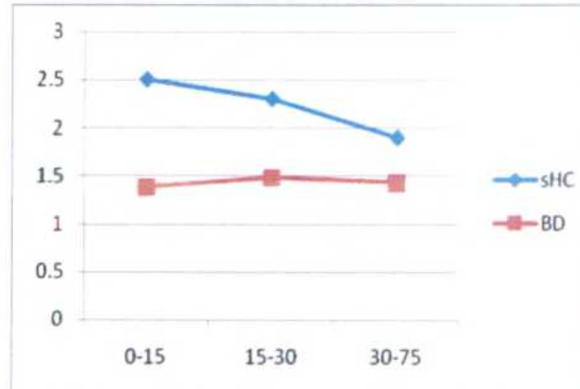
Fig. 4.2. Depth fraction of saturated hydraulic conductivity (cm hr^{-1}) and bulk density (Mg m^{-3}) of Entisols of Marathwada

Table 4.7. Physical properties of Inceptisols of Marathwada

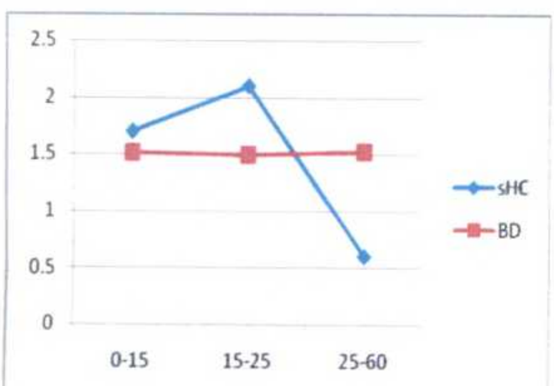
Sr.no	Agro-ecological Zone	Pedon	Horizons	Depth (cm)	SHC (cm hr^{-1})	Bulk density (Mg m^{-3})	Particle size distribution (%) (< 2mm)			Textural class
							Sand	Silt	Clay	
1	6.1 Drought Prone zone	Aurangabad P9	Ap	0-13	1.4	1.52	25.3	19.8	54.9	c
			A	13-25	1.3	1.54	24.8	19.1	56.1	c
			Bw	25-45	2.0	1.56	26.4	21.8	51.8	cl
		Ausa P11	Ap	0-15	2.5	1.39	21.8	26.9	51.3	cl
			B	15-30	2.3	1.48	23.3	23.9	53.1	c
			Bw	30-75	1.9	1.43	34.3	17.9	47.8	c
		Gevrai P13	Ap	0-15	1.7	1.51	14.8	32.4	52.8	cl
			B	15-25	2.1	1.49	16.5	29.8	53.7	cl
			Bw	25-60	0.6	1.52	16.9	30.1	53.2	c
2	6.2 Assured Rainfall zone	Lohagaon P12	Ap	0-15	2.1	1.35	24.6	23.8	51.6	c
			B	15-45	2.5	1.38	18.4	28.6	53.2	c
			Bw	45-75	1.1	1.48	17.1	33.1	48.4	scl
3	6.4 Transistionally high rainfall zone	Mandawa P10	Ap	0-15	1.2	1.58	21.5	24.2	54.3	c
			A	15-45	2.1	1.59	22.8	21.3	55.9	c
			Bw	45-60	1.0	1.58	28.7	19.7	51.8	c



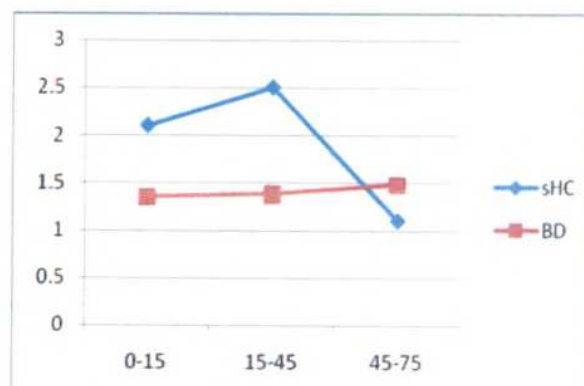
Pedon 9



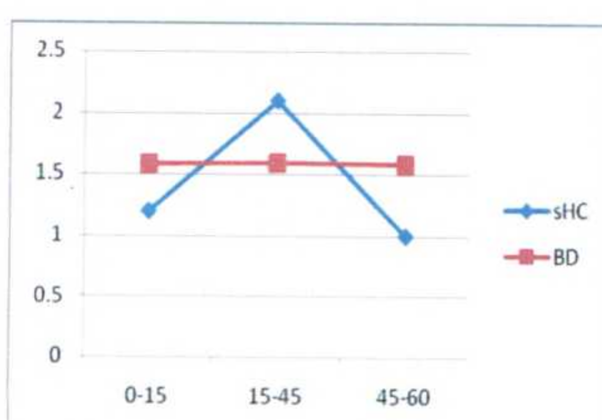
Pedon 11



Pedon 13



Pedon 12



Pedon 10

Fig. 4.3. Depth fraction of saturated hydraulic conductivity (cm hr^{-1}) and bulk density ($Mg\ m^{-3}$) of Inceptisols of Marathwada

from 47.0 to 56.1 per cent and the bulk density ranged from 1.35 to 1.59 Mg m^{-3} indicating it's increase with depth of the profiles.

The saturated hydraulic conductivity of Inceptisols Table 4.7 and Fig. 4.3 varied from 1.1 to 4.3 cm hr^{-1} indicating the favorable influence of Ca ions in improving hydraulic properties of soils. The saturated hydraulic conductivity of Lohagaon pedons of Assured rainfall zone is slightly higher than other soils of Drought prone zone. Similar, result were as reported by Patil, (2010).

4.1.4.3 Physical properties of Vertisols of Marathwada.

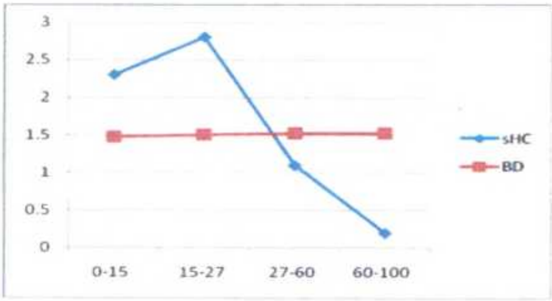
The particle-size analysis data are presented in Table 4.8. All the pedons showed clayey in texture and the clay content ranged between 50.1 to 62.1. The clay content in all the pedons was slightly increases with depth, which is well observed in Vertisols of central India (Kadu, 2003). The sand content of the pedons ranged between 9.7 to 21.6 %. The silt content ranges from 23.4 to 32.6. The uniformly higher clay content was observed in the pedon P16. Bharaswada of assured rainfall zone and pedon P15 of Hadgaon of the moderately high rainfall zone. Sand content observed less in Hadgaon profile where as silt content was low in Bharaswada pedon.

The Bulk density value ranges from 1.27 to 1.56 Mg m^3. However, the majority of Vertisols have BD $\geq$1.27 Mg m^3 (Table 4.8 and Fig. 4.4). The BD values greater than 1.4 Mg m^{-3} may pose problem for root penetration (FAO, 1995). Despite this recent findings (Kadu *et al*; 2003) indicated that in Vertisols of central India with BD of > 1.4 Mg m^{-3}, an optimum yield of cotton (18 q ha^{-1} of seed + lint) is generally obtained by farmers under rained conditions. Govindpur and Wadgaon pedons have slightly lower bulk density than other pedons.

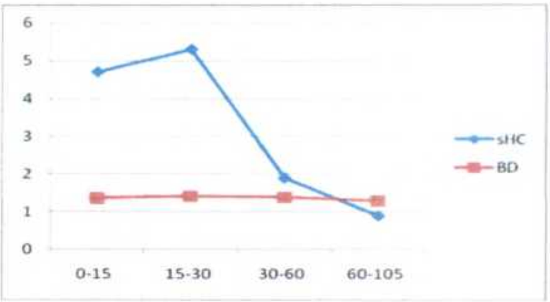
The saturated hydraulic conductivity of Vertisols varied from 0.1 to 5.3 cm hr^{-1}. In pedon 15 and 16 the SHC varied from 0.4 to 2.0 cm hr^{-1}. Hydraulic conductivity in pedon 14,17, 18.19 and 20 decreased rapidly with depth and <1cm hr^{-1} (Fig 4.4). It indicates the favorable influence of Ca ions in improving hydraulic properties of soils. The highest saturated hydraulic conductivity of surface soil is less as compared to surface in drought prone zone as compared to Assured rainfall and moderately high rainfall zone (Table 4.8).

Table 4.8 Physical properties of Vertisols of Marathwada

Sr. no	Agro-ecological Zone	Pedon	Horizons	Depth (cm)	SHC cm hr^{-1}	Bulk density (Mg m^{-3})	Particle size distribution (%)(< 2mm)			Textural class
							Sand	Silt	clay	
1	6.1 Drought Prone zone	Beed P14	Ap	0-15	2.3	1.48	16.8	30.1	53.1	c
			A	15-27	2.8	1.51	14.6	29.8	55.6	c
			Bw	27-60	1.1	1.53	20.6	27.6	51.8	cl
			Bssk	60-100	0.2	1.53	16.1	25.1	58.9	cl
		Govindpur P17	Ap	0-15	4.7	1.36	17.2	31.6	51.2	c
			A	15-30	5.3	1.41	16.1	31.1	52.7	cl
			Bw	30-60	1.9	1.39	15.8	29.1	55.1	cl
			Bssk	60-105	0.9	1.29	14.2	27	58.8	cl
		Wadgaon P18	Ap	0-15	2.5	1.29	19.8	28.1	52.2	c
			A	15-33	2.7	1.32	17.9	28.4	53.7	c
			Bss1	33-65	0.9	1.36	16.2	28.2	55.6	c
			Bssk	65-100	0.4	1.27	14.9	27.8	57.3	cl
		Latur P19	Ap	0-25	1.0	1.30	21.6	28.4	50.1	c
			Bw1	25-60	1.4	1.31	18.03	30.27	51.7	c
			Bw2	60-90	1.1	1.40	16.1	30.8	53.1	c
			Bssk	90-120	0.9	1.42	15.8	28.3	55.8	cl
		Babulgaon P20	Ap	0-20	1.0	1.39	21.2	26.7	52.1	c
			Bw1	20-45	2.1	1.48	20.3	26.5	53.2	cl
			Bw2	25-90	0.4	1.42	19.4	26.2	54.4	cl
			Bssk	90-110	0.1	1.41	10.1	32.9	56.8	cl
2	6.2 Assured rainfall zone	Bharaswada P16	Ap	0-15	1.3	1.37	19.9	23.4	56.7	c
			A	15-35	2.0	1.48	15.6	26.8	57.8	c
			Bw	35-65	0.9	1.47	18.2	27.1	54.7	c
			Bssk	65-102	0.4	1.32	10.2	30.7	59.3	c
		Chudawa P21	Ap	0-13	0.9	1.51	16.8	31.1	52.1	cl
			B	13-32	1.2	1.52	15.2	32.6	52.8	c
			Bw	32-68	0.6	1.52	16.6	29.4	53.7	c
			Bss	68-100	0.5	1.53	20.0	24.9	55.1	cl
3	6.3 Moderately high rainfall zone	Hadgaon P15	Ap	0-15	0.5	1.52	15.8	27.1	57.1	c
			A	15-40	1.0	1.54	12.8	28.7	59.2	c
			Bw	40-65	0.4	1.56	16.7	31.8	51.2	c
			Bssk	65-105	1.9	1.55	9.7	28.3	62.1	c



Pedon 14



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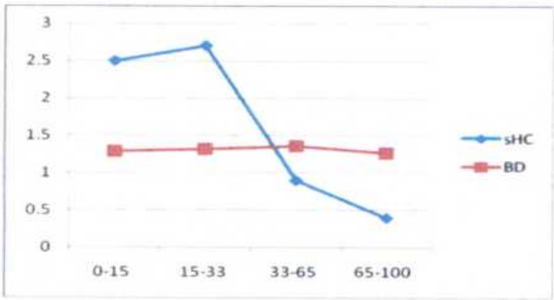

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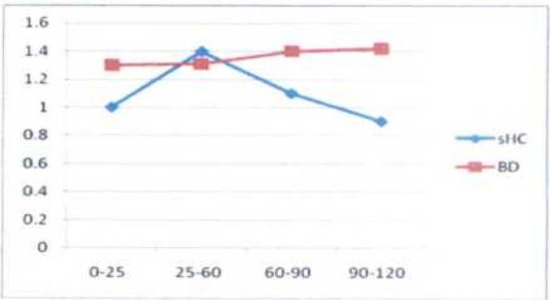

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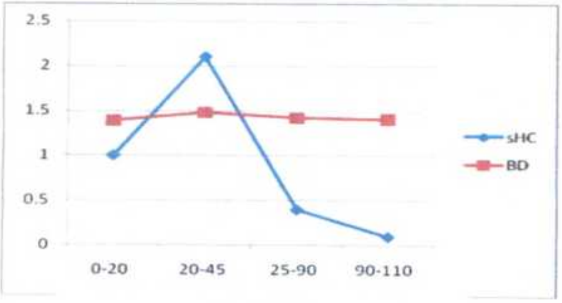

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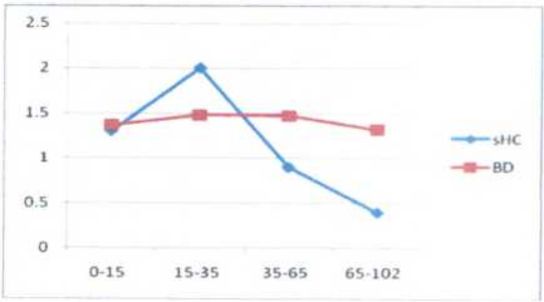

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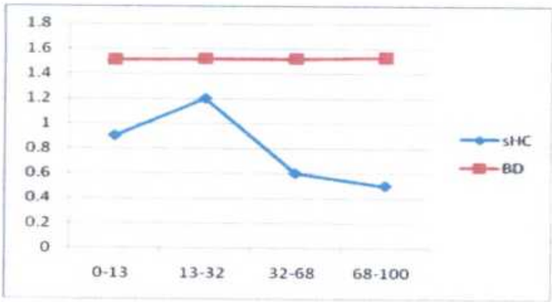

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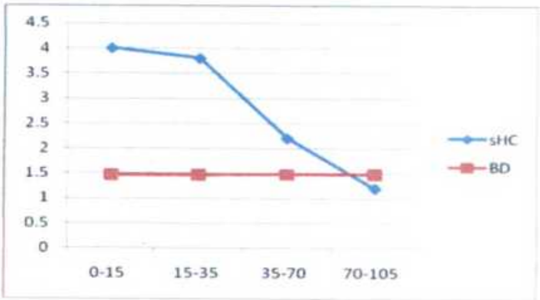

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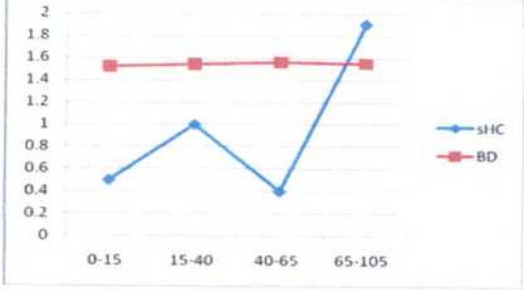


Pedon 15

Fig. 4.4. Depth fraction of saturated hydraulic conductivity (cm hr^{-1}) and bulk density ($Mg\ m^{-3}$) of Vertisols of Marathwada

4.1.5 Chemical Properties

4.1.5.1 Chemical properties of Entisols of Marathwada.

The data on chemical properties of the eight pedons studied are presented in Table 4.9. The pH of Entisols (1:2.5 Soil-water suspension) ranged between 6.5 to 8.6, i.e slightly acid to strongly alkaline reaction (Table 4.9), which increased with depth in most of the pedons. The maximum pH value was observed in pedon 5, 6, 7 and 8 (pH 8.0 to 8.6) and minimum in pedon 2 and 3 (pH 6.5 to 7.4). The increase in the pH values appear to be related to increase in $CaCO_3$.

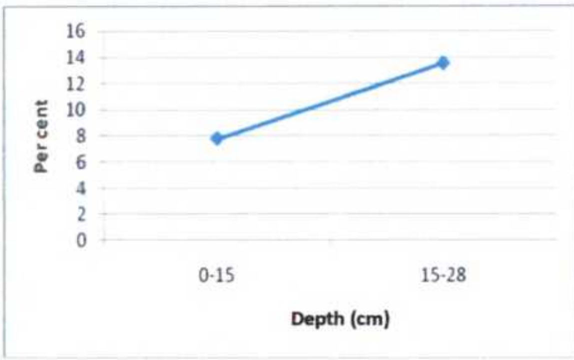
Electrical conductivity of different profiles ranged from 0.118 to 1.77 dS m^{-1} at 25°C (Table 4.9), which increased with depth in all pedons except pedon 3, 4 and 8. This is perhaps because of the soils considerably varied in the rates of leached out salts from the sampling sites. The electrical conductivity of Dhasadi pedon is considerably high (1.77 dS m^{-1}) which may be attributed to the indiscriminate use of irrigation water.

The organic carbon content in these soils ranged from 2.8 to 10.40 g kg^{-1} which is low to moderate and in general decreased with depth except pedon 2,3 and 7 (Table 4.9). Despite the addition of regular foliage and root accumulation as organic matter in soil, the organic carbon has not been improved due to high rate of decomposition of semi-arid environment (Velayutham *et al.,* 2000). However, recent investigation indicated that there in an increasing trend of organic carbon stock in black soils due to their continuous cropping with better management. The $CaCO_3$ content ranged from 5.9 to 18.1 per cent in different Entisols. It increased with depth in all the pedons. The highest calcium carbonate was observed in Transistionally high rainfall zone.

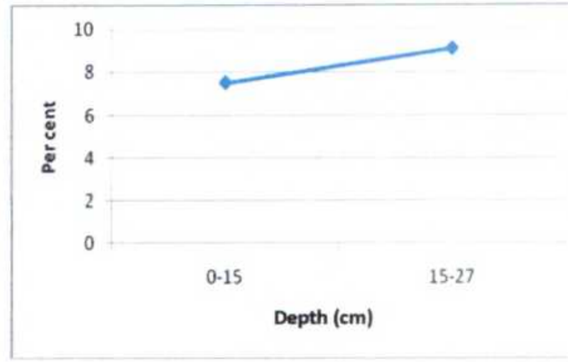
The CEC of different soil profiles ranged from 31.2 to 67.1 cmol (P^+) kg^{-1}. The maximum value recorded in pedon P2 drought prone zone. The CEC of the soils mainly depends on the amount and the nature of clay, organic matter content and pH (Brady, 1984).

Table 4.9. Chemical properties of Entisols of Marathwada.

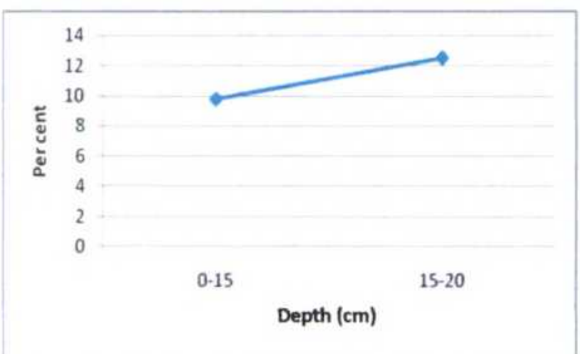
Sr. no	Agro-ecological Zone	Pedon	Horizon	Depth (cm)	pH	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	$CaCO_3$ (%)	CEC (cmol $p+\ kg^{-1}$)
1	6.1 Drought Prone zone	Vaijapur P1	Ap	0-15	7.8	0.739	5.26	7.8	56.1
			A	15-28	7.8	0.780	2.80	13.5	53.2
		Kej P2	Ap	0-15	7.4	0.170	7.61	7.5	67.1
			A	15-27	7.4	0.275	8.19	9.1	66.5
		Ter P5	Ap	0-15	8.1	0.242	6.24	9.8	51.5
			Ac	15-20	8.0	0.352	5.25	12.5	53.1
		Amhadpur P6	Ap	0-15	8.0	0.369	5.29	13.2	61.2
			A	15-25	8.3	0.363	4.29	16.8	62.8
		Laman Tanda P7	Ap	0-15	8.3	0.150	7.41	8.5	45.5
			Ac	15-30	8.4	0.118	7.99	13.8	31.2
2	6.2 Assured rainfall	Dhasadi P8	Ap	0-15	8.6	1.770	5.41	9.5	43.4
			Ap	15-26	8.6	1.130	4.28	14.8	47.1
3	6.3 Transistionally high rainfall	Kinwat P3	Ap	0-15	6.5	0.214	8.77	5.9	60.1
			C	15-20	6.8	0.155	10.40	6.1	62.2
		Rohadi P4	Ap	0-15	7.3	0.632	4.29	11.5	50.1
			A	15-26	7.4	0.432	3.31	18.1	54.3



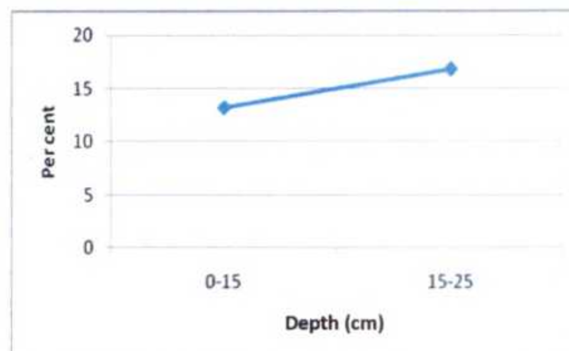
Pedon 1



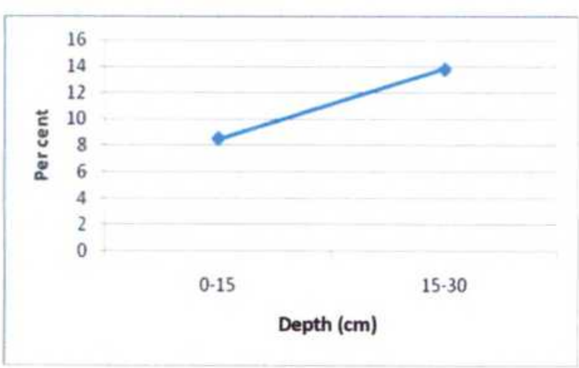
Pedon 2



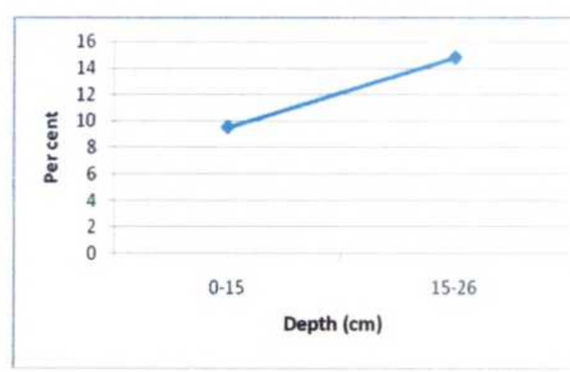
Pedon 5



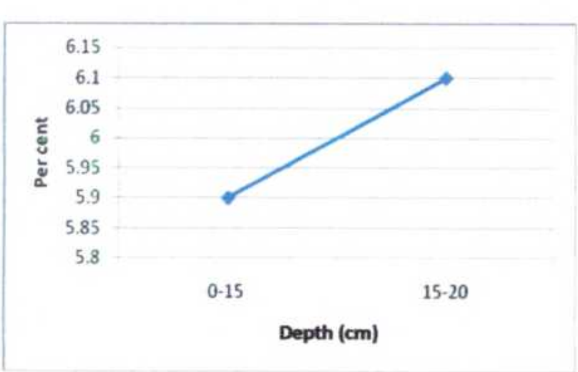
Pedon 6



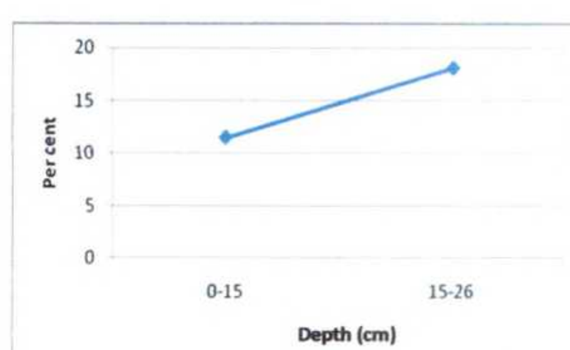
Pedon 7



Pedon 8



Pedon 3



Pedon 4

Fig. 4.5. Depth fraction of calcium carbonate density of Entisols of Marathwada

4.1.5.2 Chemical properties of Inceptiosols of Marathwada.

The pH of Inceptisols ranged between 7.8 to 8.3, i.e slightly alkali to moderate alkaline in reaction. The values of electrical conductivity ranged from 0.225 to 2.0 dsm^{-1} at 25°C (Table 4.10), different horizons of these profiles which increased with depth in most of the pedons except pedon 10 and 11 where opposite trend in pH was noticed. The maximum pH value was observed in pedon 13 (Beed).

The organic carbon was ranged from 2.3 to 9.75 g kg^{-1} it was observed highest content in pedon P10 (Mandwa) of Nanded District Transitionally high rainfall zone and very low in pedon P9 (Aurangabad) drought prone zone Waikar *et al.* (2004) also reported. The organic carbon decreased with the increasing depth of the soil profiles.

Calcium carbonate ranged from 3.80 to 14.50 percent majority of soils profiles in dictating increase in $CaCO_3$ with depth of the profiles. The calcareousness in Inseptisols is due to the presence of both pedogenic and non-pedogenic $CaCO_3$ (Pal *et al.*, 2000).

The CEC of different soil profiles was in the range of 33.3 to 63.5 cmol (p^+) Kg^{-1}. The maximum value recorded pedon P11 Drought porne zone followed by pedon 12 Assured rainfall zone. The CEC in these profiles decreased with increasing depth of soil.

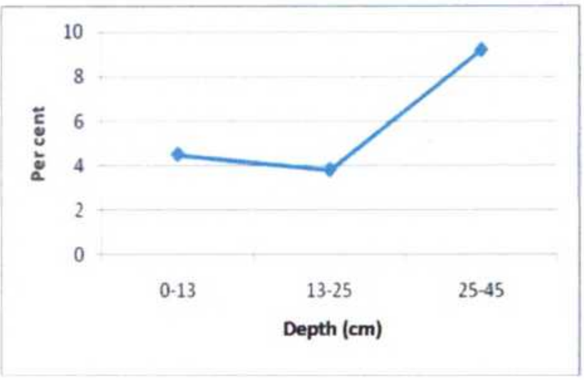
4.1.5.3 Chemical properties of Vertisols of Marathwada.

The pH of the Vertisols profiles (1:2.5 soil water suspension) ranged between 7.8 to 8.7 i.e. alkali to moderate alkaline reaction (Table 4.11). The values of electrical conductivity ranged from 0.20 to 1.35 dsm^{-1} at 25°C. The maximum pH value was observed in pedon 15 and 17 (8.1 to 8.7) and minimum in pedon 14,18 and 20 (pH 7.8 to 8.2) except pedon 16 and 20 which, increased with depth in most of pedon (Table 4.11). The permeability of shallow soil is more and leaching is faster as compared to deep soils alkaline pH was increased with depth (Vertisols). Malewar (1995). Similar observation in soil pH ranging from 5.4 to 9.15 in Vertisols and Alfisol soil series of Western Maharashtra were reported by Pharande *et al.* (1996). Waikar *et al.* (2004) and Dwivedi *et al.* (2005).

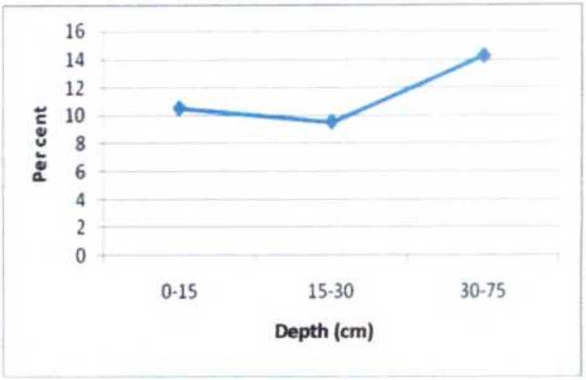
The organic carbon content in Vertisols ranged from 0.95 to 10.4 g kg^{-1} which is low to moderate. (Table 4.11) It was observed that as depth increased per cent of organic carbon decreased. The organic carbon content was

Table 4.10. Chemical properties of Inceptisols of Marathwada.

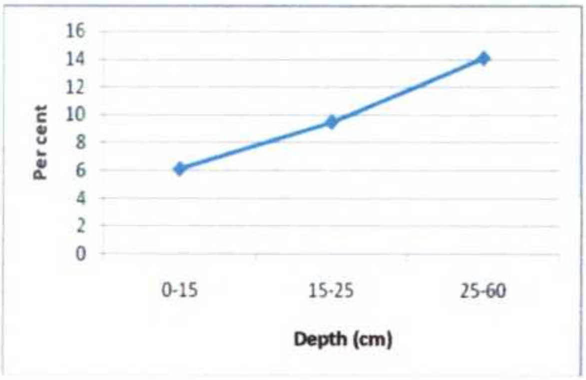
Sr. no	Agro-ecological Zone	Pedon	Horizons	Depth (cm)	pH	EC (dSm^{-1})	OC (gkg^{-1})	$CaCO_3$ (%)	CEC (cmol p+ kg^{-1})
1	6.1 Drought Prone zone	A'bad P9	Ap	0-13	8.1	0.255	5.46	4.5	51.8
			A	13-25	8.1	0.289	3.70	3.8	55.6
			Bw	25-45	8.2	0.370	2.34	9.2	49.3
		Ausa P11	Ap	0-15	8.1	1.020	9.55	10.5	52.1
			B	15-30	7.9	1.170	4.75	9.5	53.5
			Bw	30-75	8.0	0.398	2.92	14.2	51
		Gevrai P13	Ap	0-15	8.1	0.229	4.29	6.1	49.5
			B	15-25	8.0	0.239	3.90	9.5	53.2
			Bw	25-60	8.3	0.270	3.20	14.1	54.2
2	6.2 Assured rainfall zone	Lohagaon P12	Ap	0-15	8.2	1.120	6.28	6.3	52.1
			B	15-45	8.1	1.210	4.32	5.0	54.3
			Bw	45-75	8.2	2.000	3.11	7.8	33.3
3	6.4 Transistionally high rainfall zone	Mandawa P10	Ap	0-15	7.9	0.457	9.75	11.4	47.1
			A	15-45	7.8	0.397	7.60	13.0	52.3
			Bw	45-60	7.8	0.300	5.26	14.5	41.7



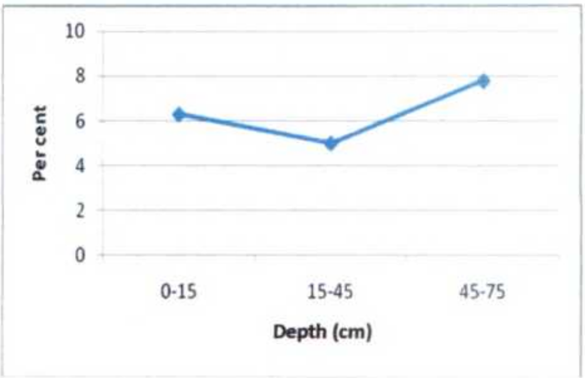
Pedon 9



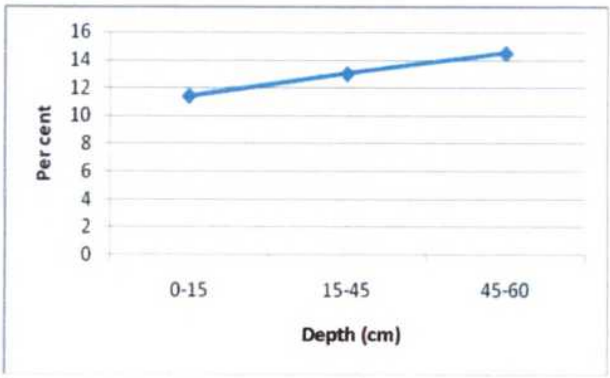
Pedon 11



Pedon 13



Pedon 12

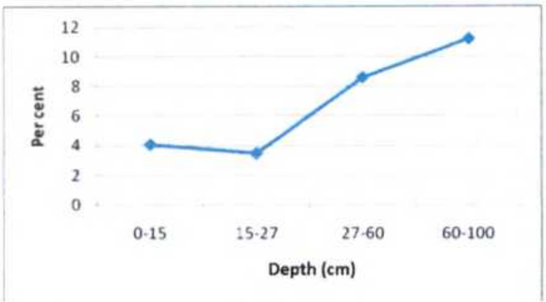


Pedon 10

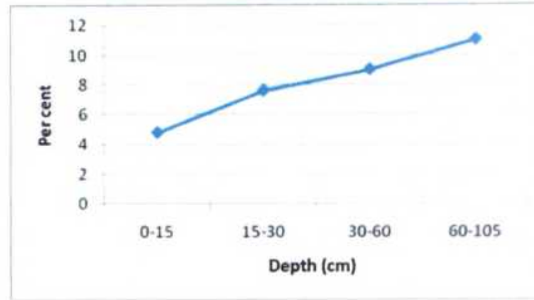
Fig. 4.6. Depth fraction of calcium carbonate density of Inceptisols of Marathwada

Table 4.11. Chemical properties of Vertisols of Marathwada.

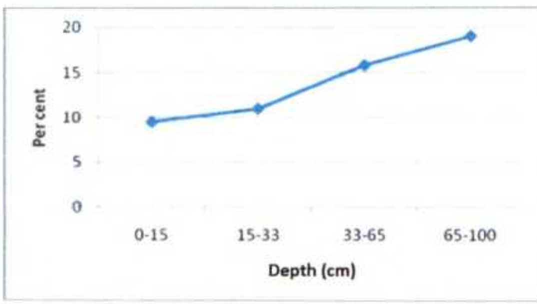
Sl.no	Agro-ecological Zone	Pedon	Horizo	Depth (cm)	pH	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	$CaCO_3$ (%)	CEC ($cmol\ p+\ kg^{-1}$)
1	6.1 Drought Prone zone	Beed P14	Ap	0-15	8.0	0.270	6.24	4.1	59.2
			A	15-27	7.8	0.286	5.85	3.5	62.1
			Bw	27-60	8.1	0.231	5.62	8.6	62
			Bssk	60-100	7.9	0.261	3.31	11.2	59.1
		Govindpur P17	Ap	0-15	8.1	0.254	9.94	4.8	45.4
			A	15-30	8.5	0.288	6.24	7.6	47.1
			Bw	30-60	8.3	0.346	5.24	9.0	51.6
			Bssk	60-105	8.4	0.560	2.92	11.0	41.3
		Wadgaon P18	Ap	0-15	8.0	0.233	9.75	9.5	48.9
			A	15-33	7.9	0.269	7.21	11.0	51.5
			Bss1	33-65	7.9	0.204	5.46	15.8	56.3
			Bssk	65-100	8.1	0.290	4.09	19.0	40.3
		Latur P19	Ap	0-25	8.1	0.291	6.82	2.8	55.8
			Bw1	25-60	8.0	0.287	6.24	3.8	52.1
			Bw2	60-90	8.3	0.337	4.29	3.0	62.5
			Bssk	90-120	8.3	0.345	3.51	5.0	40.5
		Babulgaon P20	Ap	0-20	8.2	0.470	10.04	4.8	77.5
			Bw1	20-45	8.1	0.238	8.77	4.0	76.1
			Bw2	25-90	8.0	0.203	6.82	6.5	78.2
			Bssk	90-110	8.3	0.221	3.90	11.5	68.2
2	6.2 Assured rainfall zone	Bharaswada P16	Ap	0-15	8.1	0.255	7.41	5.8	51.2
			A	15-35	8.0	0.230	6.41	5.5	54.7
			Bw	35-65	8.1	0.237	2.92	11.5	61.1
			Bssk	65-102	8.2	0.227	1.95	16.8	41.5
		Chudawa P21	Ap	0-13	8.3	0.432	5.29	11.5	57.0
			B	13-32	8.3	0.513	3.61	11.8	59.1
			Bw	32-68	8.4	0.526	2.18	12.3	61.2
			Bss	68-100	8.4	0.561	2.10	12.9	51.1
		Ranjani P22	Ap	0-15	8.1	0.238	6.31	13.0	60.0
			Bw1	15-35	8.1	0.331	4.33	12.5	62.4
			Bw2	35-70	8.2	0.368	2.93	13.8	63.1
			Bssk	70-105	8.3	0.413	2.02	14.2	58.1
3	6.3 Moderately high rainfall zone	Hadgaon P15	Ap	0-15	8.4	0.635	6.24	7.5	45.5
			A	15-40	8.7	0.444	5.07	14.1	47.3
			Bw	40-65	8.4	0.591	3.51	7.8	66.2
			Bssk	65-105	8.5	0.600	1.95	18.9	38.2



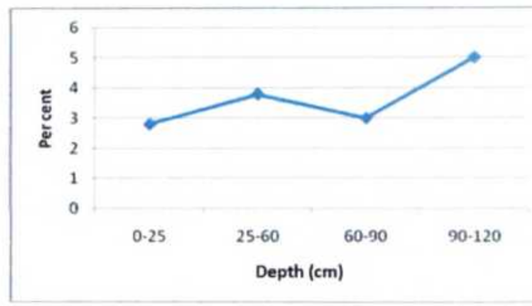
Pedon 14



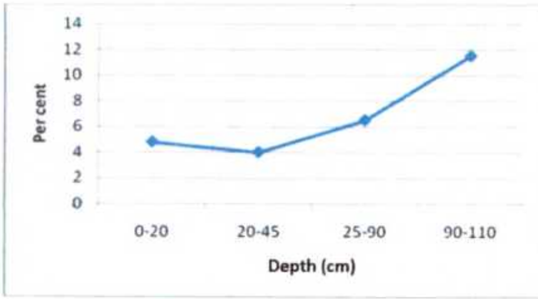
Pedon 17



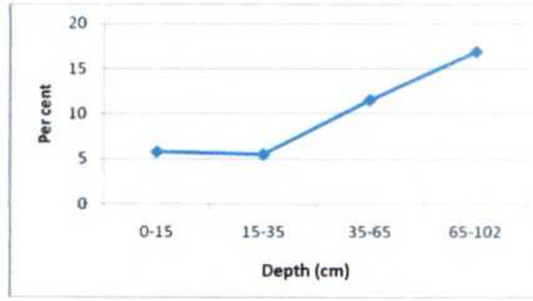
Pedon 18



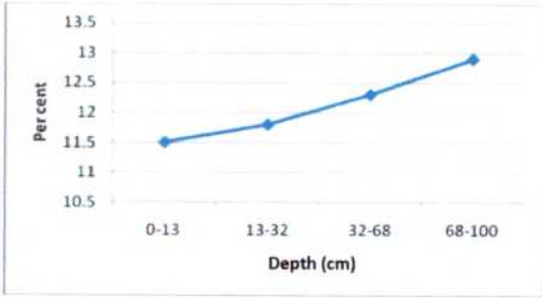
Pedon 19



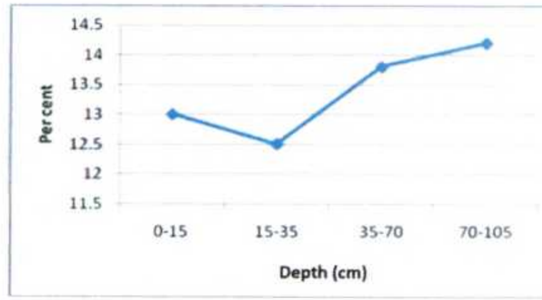
Pedon 20



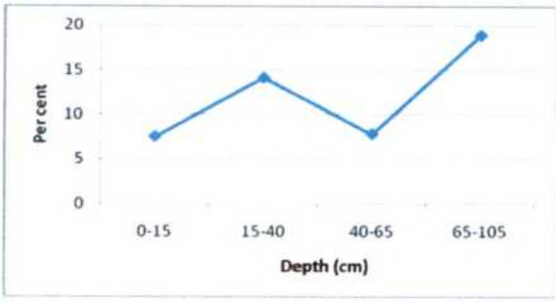
Pedon 16



Pedon 21



Pedon 22



Pedon 15

Fig. 4.7. Depth fraction of calcium carbonate density of Vertisols of Marathwada

very low near to ***murrum*** layer as compared to the overlying horizons. Despite the addition of regular foliage and root accumulation as organic matter in soils, the organic carbon has not been improved due to high rate of decomposition of semi arid environment (Velyutham *et. al*, 2000). However recent investigations indicated that there is an increasing trend of organic carbon stock in black soils due to their continuous cropping with better management. Similar range of organic carbon was reported in soils of Jayakwadi Command Area in Marathwada (Bharambe and Ghonsikar, 1985). The organic carbon was observed higest in Babulgaon pedon P20 (10.42 g kg^{-1}) of Drought prone zone. The similar content of organic carbon was also observed in lateritic soils of Konkan region (Dongale *et al.*, 1987) and Bench terraced soils of konkan (Patil *et al.*, 1987). These results are also in accordance with the findings of Malewar (1995), Pharande *et al.* (1996), Diwale and Chavan (1999) and Patil and Meisheri (2004).

Calcium carbonate ranged from 2.8 to 18.9 percent in majority of soils it was uniform with depth. However, in soil pedon 16, 17, 18 and 19, it increased with depth. Calcareousness in Vertisols is due to the presence of both pedogenic and non-pedogenic $CaCO_3$ (Pal *et al* 2000), since both the forms react with HCl, it is difficult to distinguish one from to the other.

The cation exchange capacity did not show any regular trend with depth. Vertisols developed on basalt and limestone were characterized by relatively higher CEC and it was varied from 38.2 to 78.2 cmol (p+) kg^{-1}. The highest CEC was observed in profile of Drought prone zone and it was high in depth because nature of clay, organic matter content and pH (Brady, 1984).

4.1.6 Nutrient Status of Marathwada

It has been common practice to study the distribution of available N, P and K, total N, P and S with carbon ratios in soil. The extensively occurring

Table 4.12. Available macro nutrient status of Entisols of Marathwada.

Sr. No	Agro-ecological Zone	Pedon	Horizon	Depth (cm)	Available nutrient					
					N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
1	6.1 Drought prone zone	**Vaijapur P1**	Ap	0-15	128.6	7.20	299.7	11.67	12.3	6.9
			A	15-28	82.3	2.60	293.2	7.93	10.5	6.2
		Kej P2	Ap	0-15	244.0	12.60	276.5	9.87	16.3	8.1
			A	15-27	189.3	2.60	270.3	3.46	12.5	7.5
		Ter P5	Ap	0-15	90.9	6.10	203.8	11.63	18.6	8.2
			Ac	15-20	72.1	2.00	215.3	2.93	12.1	6.24
		Amhadpur P6	Ap	0-15	156.0	4.10	423.6	9.45	16.4	7.21
			A	15-25	125.4	1.80	435.9	6.40	10.5	6.1
		Laman Tanda P7	Ap	0-15	150.5	8.40	409.0	9.61	14.3	6.81
			Ac	15-30	128.5	1.90	201.8	3.50	12.2	6.54
2	6.2 Assured rainfall zone	**Dhasadi P8**	Ap	0-15	159.9	2.40	460.7	9.61	18.8	7.24
			Ap	15-26	131.7	1.80	369.8	2.82	14.9	6.24
3	6.4 Transitionally high rainfall zone	**Kinwat P3**	Ap	0-15	181.9	8.10	265.4	8.78	10.2	5.5
			C	15-20	159.2	2.80	263.0	2.36	10	5.1
		Rohadi P4	Ap	0-15	97.2	4.50	163.9	9.56	21.6	10.2
			A	15-26	103.5	2.10	136.7	9.79	18.2	8.1

swell-shrink soils of the region are subjected to agro-ecological zones with variety of crops of varying nutrient dynamic and relationship with soil properties with carbon ratios characteristics since a long, which leads to nutrition imbalance. It is therefore, very important to know the status of N, P and K in Entisols, Inceptisols and Vertisols of Marathwada region of Maharashtra, so as to have an estimate of probable quantity of nutrients present.

4.1.6.1 Macronutrient status of Entisols of Marathwada.

The data on status of available N in Entisols of Marathwada region (Table 4.12) showed that the available nitrogen content of these soils was ranged from 72.1 to 244.0 kg ha^{-1} with a mean value of 137.57 kg ha^{-1}. The highest available N and P content was recorded in a pedon P2 (Kej) surface layer. The available phosphorus content in these soils was ranged from 1.80 to 12.60 kg ha^{-1} with mean 4.43 kg ha^{-1} i.e. available nitrogen and phosphorus under very low and medium category was found to be respectively. The highest available N and P content in soil was recorded in a pedon P2 Kej surface layer of soil of Drought prone zone.

The status of available potassium content varied from 136.7 to 460.7 kg ha^{-1} with an average value of 293.02 kg ha^{-1}, which can be rated a medium category. The highest available Potassium was reported in a pedon P8 (Dhasadi) in Assured rainfall zone. The content of available Potassium is high in surface layer than subsurface layer

The available sulphur varied from 2.36 to 11.67 mg kg^{-1}. The highest sulpur was observed in Vaijaur (Pedon 1) of Drought prone zone and it was mainly decreased with increasing depth of soil profile.

Among the cations, calcium and magnesium is the dominant one followed by potassium in all Entisols. The Ca and Mg varied from 10 to 21.6 and 5.1 to 10.2 percent.

4.1.6.2 Macronutrient status of Inceptisols of Marathwada.

The available N, P and K in soils of Inceptisols of Marathwada region are reported and their characterizations are presented in table 4.13. The data showed that available nitrogen content of these soils was ranged from 37.6 to

Table 4.13. Available macro nutrient status of Inceptisols of Marathwada.

Sr. No	Agro-ecological Zone	Pedon	Horizon	Depth cm	Available nutrient					
					N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
1	6.1 Drought prone zone	A'bad P9	Ap	0-13	112.8	11.2	317.0	27.96	12.3	5.64
			A	13-25	94.1	7.2	349.2	11.67	10.2	5.5
			Bw	25-45	80.3	3.1	309.7	3.01	11.8	6.71
		Ausa P11	Ap	0-15	97.2	10.8	317.2	11.05	16.2	8.74
			B	15-30	75.3	7.1	259.5	8.47	12.3	6.72
			Bw	30-75	37.6	4.8	224.9	5.80	13.8	5.93
		Gevrai P13	Ap	0-15	163.1	10.3	318.8	7.23	12.8	6.21
			B	15-25	247.0	3.8	292.7	2.96	10.1	6.1
			Bw	25-60	87.8	2.6	304.5	1.06	10	6.24
2	6.2 Assured Rainfall zone	Lohagaon P12	Ap	0-15	166.2	11.8	583.6	10.43	18.6	8.32
			B	15-45	172.5	4.9	546.3	8.78	12.3	5.67
			Bw	45-75	80.2	2.6	382.9	1.56	13.6	6.72
3	6.4 Transistionally high rainfall zone	Mandawa P10	Ap	0-15	150.5	8.6	472.4	27.96	11.6	7.21
			A	15-45	158.0	2.3	406.9	11.51	10.5	6.24
			Bw	45-60	69.0	1.5	292.7	2.17	10	6.51

247.0 kg ha^{-1} with a mean value 143.6 kg ha^{-1}. The highest available nitrogen content was recorded in pedon P13 of Gevrai of Drought pronė zone.

The available phosphorus and potassium content in soils were varied from 1.5 to 11.8 and 224.9 to 583.6 kg ha^{-1} with a mean value of 5.8 and 363.8 kg ha^{-1}, respectively. The highest available P and K were recorded in pedon P12 (Lohagaon) of Assured rainfall zone i.e. very low to moderate in available phosphorus and moderately high in potassium. These results are in line with the findings of Waikar *et al.* (2004).

The available sulphur of soil profile varied from 1.06 to 27.96 mg kg-^{1}. The maximum value of available sulphur was recorded in Aurangabad Ap horizon pedon P9 and same as Mandawa P10. The sulphur of the soils mainly decreased with increasing depth of soil profiles.

The cations of Calcium and Magnesium had the dominant one followed by potassium and CEC in all Inceptisols profiles. The Ca and Mg varied from 10.0 to 18.6 and 5.5 to 8.7 per cent. The highest Ca was observed in Assured rainfall zone and Mg was highest in Drought porne zone. There was effect of precipitation of $CaCO_3$ due to aridity may be due caused of increase in Ca and Mg.

4.1.6.3 Macronutrient status of Vertisols of Marathwada.

The data on available N, P, K and S of Vertisols are showed in table 4.14. The available N content was ranged from 51.2 to 334.8 kg ha^{-1} with a mean value of 143.6 kg ha^{-1}. The lowest N content was observed in pedon P16 (Bharaswada) in Assured rainfall zone. Whereas, the highest N content was recorded in pedon P18 (Wadgaon) of Drought prone zone. The available N content decreased with depth of soil profile.

The available phosphorus content in these soils was varied from 1.0 to 27.10 kg ha^{-1} with a mean value of 7.93 kg ha^{-1}. The lowest phosphorus content was observed in pedon P14 (Beed) while, highest phosphorus was recorded in pedon P18 (Wadgaon) in Drought prone zone. The available phosphorus content decreased with the depth of all profiles.

Table 4.14. Available macro nutrient status of Vertisols of Marathwada.

Sr. No	Agro-ecological Zone	Pedon	Horizon	Depth cm	Available nutrient					
					N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
1	6.1Drought prone zone	Beed P14	Ap	0-15	259.9	18.20	318.2	16.05	16.02	8.32
			A	15-27	125.4	2.80	404.7	10.48	10.5	6.24
			Bw	27-60	94.9	1.20	350.3	4.69	21.1	9.52
			Bssk	60-100	74.4	1.00	272.6	7.81	18.2	8.24
		Govindpur P17	Ap	0-15	128.5	16.30	403.8	18.84	12.1	7.24
			A	15-30	134.8	8.90	427.1	8.58	10.2	6.21
			Bw	30-60	97.2	3.10	348.2	2.87	14.3	6.5
			Bssk	60-105	87.8	2.00	382.5	3.02	10.5	6.13
		Wadgaon P18	Ap	0-15	206.9	27.10	583.8	20.94	14.4	7.2
			A	15-33	334.8	11.20	472.1	11.67	12.8	6.5
			Bss1	33-65	128.5	1.60	461.2	4.31	13.5	6.7
			Bssk	65-100	63.9	1.40	382.3	2.74	10.5	5.91
		Latur P19	Ap	0-25	213.2	21.20	465.8	18.84	15.3	8.1
			Bw1	25-60	194.3	6.50	438.9	10.02	14.1	7.23
			Bw2	60-90	140.1	2.80	382.7	7.23	12.5	6.52
			Bssk	90-120	90.7	1.80	337.5	2.39	11.7	6.1
		Babulgaon P20	Ap	0-20	225.8	16.10	618.2	22.69	13.8	6.7
			Bw1	20-45	100.4	3.20	512.7	9.79	12.6	6.55
			Bw2	25-90	81.5	2.10	348.7	8.81	11.7	6.2
			Bssk	90-110	69.6	1.60	317.2	2.97	10	5.71
2	6.2 Assured rainfall zone	Bharaswada P16	Ap	0-15	219.1	10.20	523.4	22.69	16.8	7.24
			A	15-35	75.4	3.40	469.5	16.63	12.4	6.1
			Bw	35-65	69.0	1.80	373.2	7.23	13.1	6.7
			Bssk	65-102	51.2	1.20	291.4	2.39	14.5	6.64
		Chudawa P21	Ap	0-13	210.0	18.1	498.4	14.3	13.08	8.22
			B	13-32	181.1	11.20	450.8	10.11	11.02	6.32
			Bw	32-68	121.3	5.6	392.3	4.31	12.81	6.12
			Bss	68-100	55.6	2.1	320.1	4.20	10.05	5.81
		Ranjani P22	Ap	0-15	223.1	16.3	513.2	15.1	12.02	7.71
			Bw1	15-35	192.3	9.7	421.2	11.30	10.03	6.37
			Bw2	35-70	90.7	6.2	383.6	8.2	11.3	5.91
			Bssk	70-105	64.8	2.3	289.6	6.3	9.80	4.81
3	6.3 Moderately high rainfall zone	Hadgaon P15	Ap	0-15	103.5	10.60	519.9	11.79	24.1	11.6
			A	15-40	222.7	4.60	303.9	9.96	18.2	7.21
			Bw	40-65	65.9	2.20	229.6	4.62	10.5	6.21
			Bssk	65-105	62.7	1.20	294.1	2.52	12.7	6.24

The potassium content was ranged from 229.6 to 618.2 kg ha^{-1} with an average value of 430.1 kg ha^{-1}.The lowest value of K was recorded in pedon P15 of (Hadgaon) of Moderately high rainfall zone while, the highest value of K content was recorded in pedon P20 (Babhulgaon) of Drought prone zone. The potassium is decreased with depth in all profile. Sulphur change its oxidation state by microbail catalysis and the change seem to be much more reversible that nitrogen and carbon reactions. The higher content of sulphur is due to regular addition of sulphur containing fertilizer and farm yard manures.

The calcium and magnesium of Vertisols varied from 10.0 to 24.10 and 5.7 to 11.6 mg kg^{-1}. The Ca and Mg is increased with depth. Among the cations Ca and Mg are the dominant one followed by potassium in all soil profile (Table 4.12). Ca and Mg were highest in Moderately high rainfall zone than Assured rainfall zone.

Thus, from the above paragraphs it was inferred that the soils of Marathwada region were low to medium in N content. The variation in available N content in soil could be attributed to the differences in their physiography, differential cultivation and management practices of these soils but also removal of N by the crop, losses through leaching, denitrification, fixation and volatization takes place. Some nitrogen is immobilized by soil microbes. These results were in confirmatory with results that available N content in deep and medium black soils varied from 160.0 to 311.0, 144.50 and 123.0 to 231.0 kg ha^{-1}. Malewar *et al.* (1998) reported that the available N content in soils of semi-arid area of Northern Marathwada was low to medium in N content and were ranged between 78.42 to 266.96 kg ha^{-1}. The variation in the available N content in soils could be due to difference in organic carbon content.

The data narrated that the maximum low available P was found in Entisols, medium available P was found in Vertisols and high available P was found in Inceptisols. So it was observed that soil of Marathwada region were low to medium in available phosphorus content. Hence, these soils were low to moderate in available phosphorus content. The variation in the availability of phosphorus might be due to variation in $CaCO_3$ content in the soil, different soil properties and

Table 4.15. Available micro nutrient status of Entisols of Marathwada.

Sr. No	Agro-ecological Zone	Pedon	Horizon	Depth (cm)	Available micronutrient ($mg\ kg^{-1}$)			
					Fe	Mn	Zn	Cu
1	6.1 Drought prone zone	Vaijapur P1	Ap	0-15	5.11	8.90	0.91	2.43
			A	15-28	3.13	10.21	0.61	1.91
		Kej P2	Ap	0-15	4.81	10.13	0.65	2.10
			A	15-27	3.53	16.05	0.28	1.90
		Ter P5	Ap	0-15	3.96	6.34	0.48	2.16
			Ac	15-20	2.40	5.61	0.28	2.50
		Amhadpur P6	Ap	0-15	3.87	14.28	0.44	1.90
			A	15-25	3.50	18.23	0.27	1.83
		Laman Tanda P7	Ap	0-15	4.17	11.28	0.39	1.67
			Ac	15-30	3.60	5.54	0.26	0.97
2	6.2 Assured rainfall zone	Dhasadi P8	Ap	0-15	4.66	11.13	0.49	2.11
			Ap	15-26	3.18	5.14	0.26	1.80
3	6.4 Transitionally high rainfall zone	Kinwat P3	Ap	0-15	5.21	17.74	0.87	3.63
			C	15-20	3.68	12.18	0.61	2.10
		Rohadi P4	Ap	0-15	4.11	13.43	0.57	1.97
			A	15-26	2.84	11.17	0.41	1.60

agronomic practices. The similar results were also reported by Bharambe *et al.* (1999) that the available P content in soils of Majalgoan command area were ranged between 9.6 to 24.0 kg ha^{-1}. Dhage *et al.* (2000) also reported the similar results in soils of Shevgaon tehsil of Ahmednagar district and Gajbe *et al.* (1976) studied the soils of Marathwada and reported that these soils were varied from 25.6 to 51.2 kg ha^{-1} in the available phosphorus content.

In general, data revealed that these soils were moderate to rich in available potassium content. This wide range of available potassium in these soils might be due to presence of feldspar and smectite (2:1) minerals, which are capable for releasing potassium, (Waikar *et al.* 2004).

Available Micronutrient status of Marathwada

The micronutrients deficiency in soils has been attributed to continuous removal of micronutrients from soil by the recently introduced fertilizer responsive improved varieties of crops, particularly cereals, which produce high biomass on fertilizer application. It reduces the concentration of micronutrients in soil solution. The distribution of micronutrient mineral is not uniform in a soil and the spatial variation is very high. Hence, the status of available micronutrients like Fe, Zn, Mn and Cu of soils of Marathwada region of Maharashtra state was studied and reported in Table 4.15, 4.16 and 4.17.

4.1.6.4 Micronutrient status of Entisols of Marathwada.

The available Fe, Zn, Mn and Cu content in soils of Marathwada region was varied between 2.40 to 5.21, 0.26 to 0.91, 5.14 to 18.23 and 0.97 to 3.63 mg kg^{-1} with an average value of 3.61, 0.49, 11.08 and 2.03 mg kg^{-1} (Table 4.15).

The available Fe and Cu content were highest in (Kinwat) pedon P3 in Transistionally high rainfall zone. The available Mn was high in (Amhadpur) pedon P6 and Zn content were observed highest in (Vaijapur) pedon P1 under Drought prone zone of Marathwada region (Table 4.15).

4.1.6.5 Micronutrient status of Inceptisols of Marathwada.

The available Fe, Zn, Mn and Cu content was varied between 2.20 to 4.79, 5.16 to 16.18, 0.21 to 1.06 and 1.57 to 4.23 mg kg^{-1} with a mean value of

Table 4.16 Available micro nutrient status of Inceptisols of Marathwada.

Sr. No	Agro-ecological Zone	Pedon	Horizon	Depth (cm)	Available micronutrient (mg kg^{-1})			
					Fe	Mn	Zn	Cu
1	6.1 Drought prone zone	A'bad P9	Ap	0-13	4.79	12.32	1.06	2.14
			A	13-25	4.32	16.17	1.02	2.10
			Bw	25-45	3.42	9.88	0.61	2.01
		Ausa P11	Ap	0-15	3.64	11.11	0.69	1.82
			B	15-30	3.29	6.43	0.49	2.10
			Bw	30-75	2.34	5.16	0.28	1.57
		Gevrai P13	Ap	0-15	3.05	16.18	0.41	3.12
			B	15-25	2.55	10.18	0.39	2.13
			Bw	25-60	2.51	9.93	0.21	2.67
2	6.2 Assured rainfall zone	Lohagaon P12	Ap	0-15	4.54	12.81	0.67	3.17
			B	15-45	3.40	11.87	0.56	4.23
			Bw	45-75	2.20	6.33	0.41	2.60
3	6.4 Transitionally high rainfall zone	Mandawa P10	Ap	0-15	4.02	11.23	0.86	2.67
			A	15-45	3.29	10.78	0.62	3.16
			Bw	45-60	2.38	7.21	0.39	1.87

3.63, 0.55, 10.1 and 2.44 mg kg^{-1} (Table 4.16). The highest value of available Fe, and Zn content was observed in (Aurangabad) pedon P9 and Mn content is (Gevrai) P13 in Drought prone zone, respectively. The Cu content was high in (Lohagaon) pedon P12 in Assured rainfall zones (Table 4.16).

In general, DTPA-Fe and Mn were relatively higher than Zn and Cu. In general, surface horizons had higher concentrations of DTPA-micronutrient cations due to higher organic carbon and biological activity (Jagdish Prasad and Gajbhiye 1999).

4.1.6.6 Micronutrient status of Vertisols of Marathwada

The available Fe, Zn, Mn and Cu content data presented in Table 4.17 showed that the available Fe, Zn, Mn and Cu found to be varied between 1.8 and 7.21, 0.41 and 1.39, 2.36 and 21.89 and 0.59 and 4.51 mg Kg^{-1}. In general available micro nutrients showed decreasing trend down the all profiles.

The available Fe, Mn, and Zn were highest in Drought prone zone as compared to Assured rainfall and Moderatly high rainfall zone.

Hence, the majority soils of Marathwada region were low in available Fe content. This low Fe content in soil was due to low amount of organic carbon and calcareous nature of these soils. These results are in confirmatory with Sharma *et al.* (2006).

The available Zn was low in Marathwada region. This low content of available Zn in these soils might be due to fact that under alkaline conditions, the zinc cations are changed largely to their oxides or hydroxides and thereby lower the availability of zinc. The similar results were also reported by Sekhon (1991) that the available Zn content ranged between 0.4 to 2.1 mg kg^{-1} among twenty soil series of India and Meena *et al.,* (2006) that the available Zn content in Tonk district of Rajasthan was ranged from 0.19 to 1.93 mg kg^{-1}.

The low status of Mn in these soils might be due to coarse texture and low organic carbon level of soils this was congenital for the intense leaching of soluble manganese. Similar results have also been reported by Singh *et al.* (1988) and high status of Mn in some soils might be due to fact that lower oxidation

Table 4.17. Available micro nutrient status of Vertisols of Marathwada.

Sr. No	Agro-ecological Zone	Pedon	Horizo	Depth (cm)	Available micronutrient (mg kg^{-1})			
					Fe	Mn	Zn	Cu
1	6.1 Drought prone zone	Beed P14	Ap	0-15	6.13	21.89	1.23	2.61
			A	15-27	4.20	14.39	0.92	3.11
			Bw	27-60	3.17	12.94	0.92	2.16
			Bssk	60-100	3.00	8.39	0.49	1.67
		Govindpur P17	Ap	0-15	5.91	12.81	0.93	4.13
			A	15-30	4.76	13.80	1.11	4.12
			Bw	30-60	3.93	2.36	0.81	4.23
			Bssk	60-105	3.51	3.09	0.61	2.22
		Wadgaon P18	Ap	0-15	6.20	15.42	1.39	3.90
			A	15-33	5.53	12.83	0.91	4.10
			Bss1	33-65	4.18	6.40	0.61	2.56
			Bssk	65-100	3.81	7.51	0.51	1.75
		Latur P19	Ap	0-25	5.52	15.66	0.91	2.83
			Bw1	25-60	5.10	12.13	0.68	3.10
			Bw2	60-90	4.37	8.17	0.49	2.01
			Bssk	90-120	3.18	6.42	0.46	0.59
		Babulgaon P 20	Ap	0-20	7.21	13.18	0.47	3.32
			Bw1	20-45	5.16	15.54	0.90	4.11
			Bw2	25-90	4.71	10.59	0.81	2.42
			Bssk	90-110	3.58	5.63	0.68	1.56
2	6.2 Assured rainfall zone	Bharaswada P16	Ap	0-15	7.11	16.80	1.32	4.51
			A	15-35	6.27	16.15	1.13	3.98
			Bw	35-65	4.14	13.04	0.82	1.77
			Bssk	65-102	4.01	10.48	0.41	1.98
		Chudawa P21	Ap	0-13	5.1	11.3	1.09	2.91
			B	13-32	4.2	9.20	0.98	2.61
			Bw	32-68	2.9	6.13	0.52	1.75
			Bss	68-100	1.8	4.40	0.43	1.01
		Ranjani P22	Ap	0-15	6.31	13.81	1.1	3.92
			Bw1	15-35	4.33	11.20	0.95	2.52
			Bw2	35-70	3.18	9.01	0.63	1.83
			Bssk	70-105	2.11	5.52	0.52	1.21
3	6.3 Moderately high rainfall zone	Hadgaon P15	Ap	0-15	5.17	14.18	0.90	2.13
			A	15-40	3.90	12.37	0.81	1.98
			Bw	40-65	4.13	8.87	0.82	1.72
			Bssk	65-105	3.29	4.98	0.51	1.67

(reduced) state of Mn were soluble than higher oxidation state at normal pH range of soils and oxidation of divalent Mn^{++} to trivalent Mn^{+++} by certain fungi and bacteria. Certain organic carbon compounds synthesized by the microorganism released by the plants as root exudation have oxidizing or reducing power. The similar observations were also reported by Hundal *et al.* (2006) that the available Mn content in Punjab soils were ranged from 0.07 to 18.56 mg kg^{-1} and Pharande *et al.* 1996 that the available Mn content in Vertisol soils of Maharatsra ranged between 7.3 to 40.1 mg kg^{-1}

The high content of available Cu in these soils might be due to presence of Cu-minerals like chalcocite, cuprite etc. in the parent material. Patil and Sonar (1994) reported that the available Cu content in swell-shrink soils of Maharashtra was ranged between 1.3 to 6.1 mg kg^{-1}. The similar results were also reported by Malewar and Randhawa (1978).

4.2 SOIL CARBON PARAMETERS AND RATIOS

The present study on organic carbon mapping was featured by various cropping systems under different land-uses representing various kinds of management levels and bioclimatic systems of Marathwada region.

Nutrient elements in soils show dynamic behavior under influence of chemical, physical and biological processes. The intensity of processes depends on environmental conditions in general and organic carbon content and association with N, P and S in particular. The data on soil organic carbon, soil inorganic carbon, Total carbon, soil microbial biomass carbon, CO_2 evaluation, carbon : nitrogen, carbon : phosphorus, carbon : sulphur ratio are presents in Table 4.18, 4.19 and 4.20.

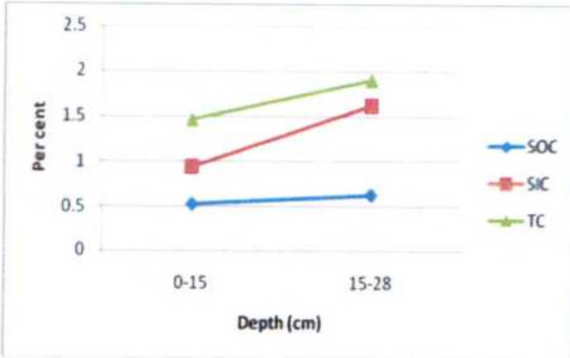
4.2.1 Soil carbon Parameters of Entisols of Marathwada

The soil organic carbon and soil inorganic carbon ranged from between 0.331 to 1.42 and 0.93 to 2.17 per cent, respectively. It was observed highest in transitionally high rainfall zone than Drought porn and assured rainfall zone and total carbon was varied from 1.68 to 3.176 per cent and its highest content was in Drought prone zone (Table 4.18 and Fig. 4.8).

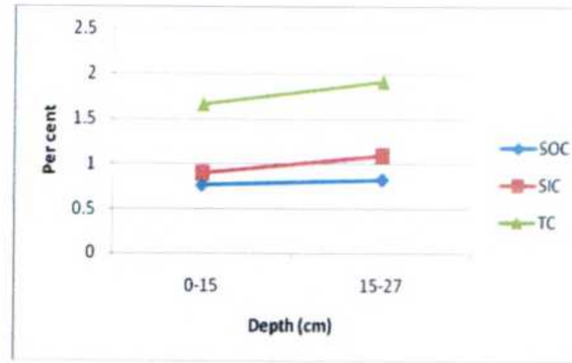
The SMBC ranged between 101.1 to 629.9 μ g^{-1} which declines rapidly with increase in depth in most of pedon. There is still contention about the degree of seasonal variation in the microbial biomass. Indications may be under most climatic regimes (Vance 1987).

Table 4.18. Soil carbon parameters and ratios of Entisols of Marathwada.

Sr. No	Agro-ecological Zone	Pedon	Horizon	Depth. (cm)	SOC (%)	SIC (%)	TC (%)	SMBC ($\mu g\ kg^{-1}$)	CO_2 (mg CO_2 kg^{-1} 24 hr^{-1})	Carbon ratio		
										C:N	C:P	C:S
1	6.1 Drought prone zone	Vaijapur P1	Ap	0-15	0.526	0.936	1.462	227.17	10.0	7.78	17.09	7.96
			A	15-28	0.628	1.62	1.906	198.10	10.5	14.36	19.60	12.86
		Kej P2	Ap	0-15	0.761	0.90	1.661	144.72	9.6	11.66	20.30	11.03
			A	15-27	0.819	1.092	1.911	120.13	10.2	11.86	23.23	12.00
		Ter P5	Ap	0-15	0.624	2.55	3.176	292.21	5.0	10.27	21.33	11.09
			Ac	15-20	0.525	1.5	2.025	190.10	9.2	9.58	18.91	9.85
		Amhadpur P6	Ap	0-15	0.529	1.584	2.113	160.90	2.6	9.79	16.78	10.21
			A	15-25	0.429	2.016	2.445	106.07	9.2	8.28	12.71	7.94
		Laman Tanda P7	Ap	0-15	0.741	1.02	1.761	592.78	7.0	11.90	24.09	12.19
			Ac	15-30	0.799	1.65	2.449	302.13	6.8	14.20	24.76	13.31
2	6.2 Assured rainfall zone	Dhasadi P8	Ap	0-15	0.541	1.14	1.681	382.11	12.0	8.90	15.34	9.12
			Ac	15-26	0.428	1.776	2.204	101.13	9.8	7.40	11.17	7.50
3	6.4 Transitionally high rainfall	Kinwat P3	Ap	0-15	0.877	0.708	1.585	629.97	11.0	12.17	18.55	12.43
			C	15-20	1.40	0.732	2.132	392.54	12.5	15.54	22.91	15.02
		Rohadi P4	Ap	0-15	0.429	1.38	1.809	227.13	6.6	6.89	15.88	7.33
			A	15-26	0.331	2.172	2.503	220.21	8.4	5.88	10.75	6.78



Pedon 1



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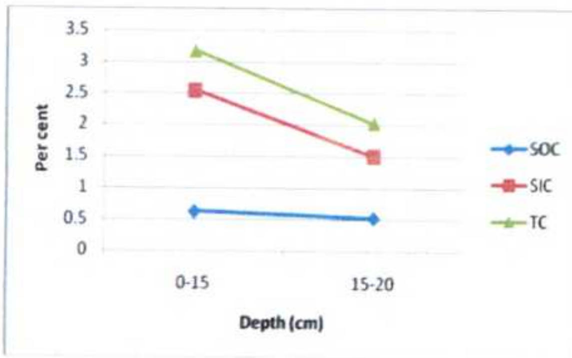

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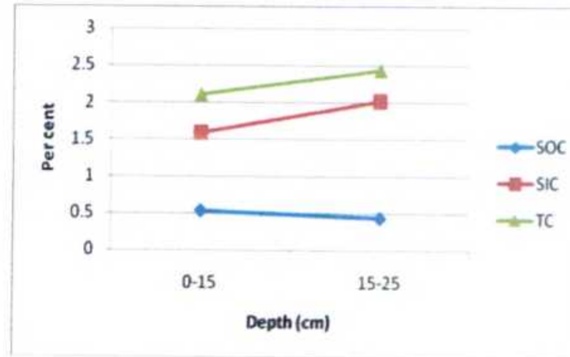

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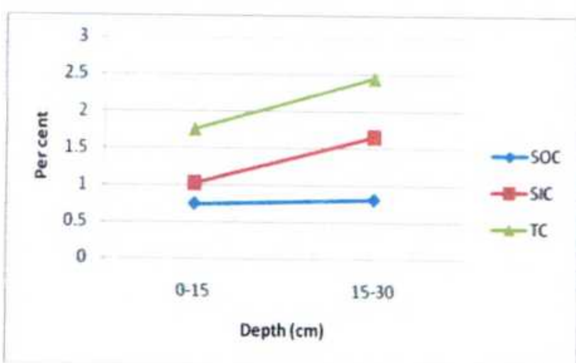
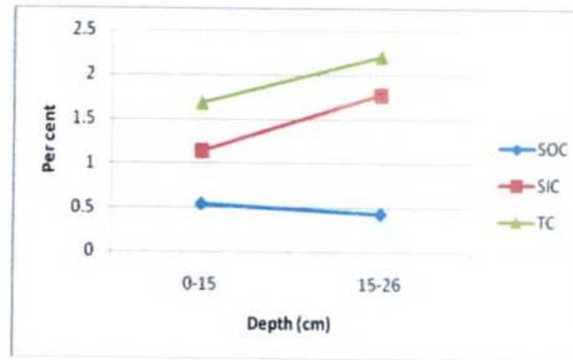
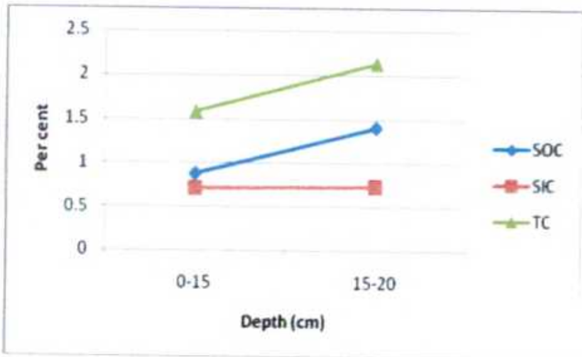


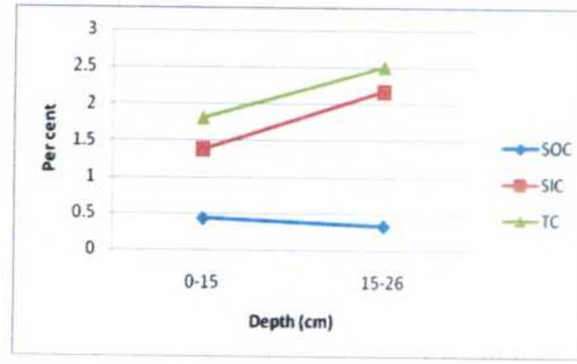
Pedon 7



Pedon 8



Pedon 3



Pedon 4

Fig. 4.8. Depth fraction of SOC, SIC and TC per cent density of Entisols of Marathwada

The CO_2 evaluation of Entisols was ranged between 2.6 to 12.5 g 100^1 g 24 hr^{-1}, respectively. The high value of CO_2 was recorded in Kinwat P3 (12.5 g 100^1 g 24 hr^{-1}) and low value was recorded in Ahamadpur P6 (2.6 g 100^1 g 24 hr^{-1}). It was observed highest in Transistinally high rainfall zone than Drought prone and assured rainfall zone. In general, it was increased in sub surface of all pedons. Soil respiration is also highly variable may be depending on substrate availability, moisture and temperature (Table 4.18).

Because, the increase in SOC increases the surface change density (SCD) of soil and the ratio of internal / external exchange sites (Poonia and Niederbudde 1990). It may be mentioned that the dominant soils in the SAT are black soil (Vertisols and their intergrades, with some inclusions of Entisols in the hills and pediments) and associated red soils. All these soils are dominated by smectites and smectite-kaolinite (Bhattacharyya *et al.,* 1993; Pal and Deshpande 1987 a & b; Pal *et al.*, 2000). Presence of smectite increases the SCD of soils, which offer greater scope of carbon sequestration in these soils. Black soils, therefore, may reach a higher quasi-equilibrium value QEV (>2%) compared to red soils dominated by Kaolin with low SCD.

C:N, C:P and C:S ratios in Entisols of Marathwada

The C:N, C:P and C:S ratios indicate the characterization of soil organic matter showing the degree of organic matter decomposition and also magnitude of decay stabilization with total soil components. The data on these ratios are tabulated in Table 4.18, 4.19 and 4.20.

The Entisols of the region varied in C:N, C:P and C:S ratios from 5.88 to 15.54 , 10.75 to 24.74 and 6.78 to 15.02 with mean values of 10.40, 18.33 and 10.41, respectively. The highest C:N and C:S ratios was observed in soil pedons of Transitionally high rainfall zone and higher C:P ratio was observed in Drought prone zone of Entisols.

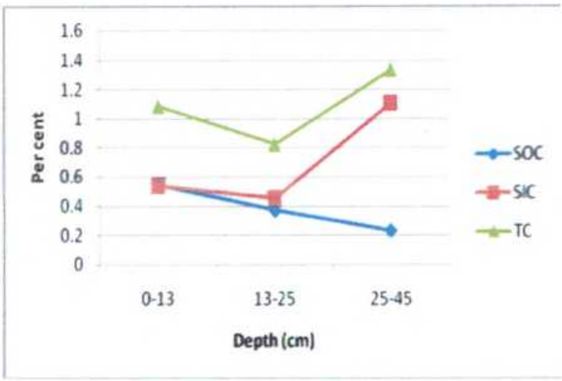
4.2.2 Soil carbon Parameters of Inceptisols of Marathwada.

The soil organic carbon, inorganic carbon and total carbon ranged between 0.234 to 0.975, 0.456 to 1.74 and 0.826 to 2.295 per cent respectively i. e. low to moderately high (Table 4.19 and Fig. 4.9).

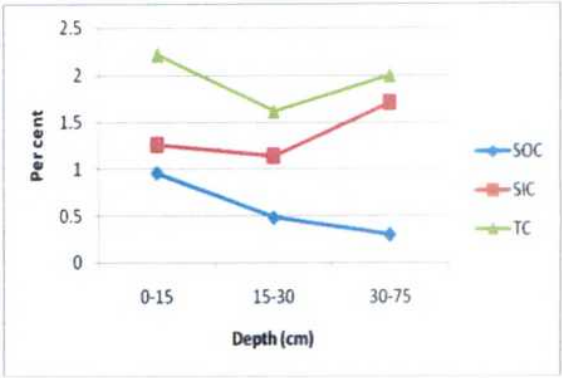
The highest carbon content was observed in Transitionally high rainfall zone than Drought prone and Assured rainfall zone. The Mandwa (P10) pedon recorded highest value of SOC (0.975 per cent) while pedon escavated at

Table 4.19. Soil carbon parameters and ratios of Incectisols of Marathwada.

Sr. No	Agro-ecological Zone	Pedon	Horizon	Depth. (cm)	SOC (%)	SIC (%)	TC (%)	SMBC ($\mu g\ kg^{-1}$)	CO_2 (mg CO_2 kg^{-1} 24 hr^{-1})	Carbon ratio		
										C:N	C:P	C:S
1	6.1 Drought prone zone	Aurangabad P9	Ap	0-13	0.546	0.54	1.086	373.30	6.8	8.56	14.27	8.36
			A	13-25	0.370	0.456	0.826	208.17	11.2	5.66	10.06	6.08
			Bw	25-45	0.234	1.104	1.338	-	-	4.10	6.93	4.27
		Ausa P11	Ap	0-15	0.955	1.26	2.215	744.34	6.0	16.75	27.08	14.80
			B	15-30	0.475	1.14	1.615	213.15	5.7	8.44	14.72	7.81
			Bw	30-75	0.292	1.704	1.996	-	-	5.98	11.11	5.55
		Gevrai P13	Ap	0-15	0.429	0.732	1.161	82.63	9.6	8.41	14.66	9.37
			B	15-25	0.390	1.14	1.53	123.20	9.0	7.32	12.68	9.28
			Bw	25-60	0.320	1.692	2.012	-	-	5.75	12.90	7.34
2	6.2 Assured Rainfall zone	Lohagaon P12	Ap	0-15	0.628	1.288	1.916	445.52	2.6	10.73	21.46	13.72
			B	15-45	0.432	0.60	1.032	302.50	7.9	9.44	18.58	9.93
			Bw	45-75	0.311	0.936	1.247	-	-	6.57	14.27	7.81
3	6.4 Transitionally high rainfall zone	Mandawa P10	Ap	0-15	0.975	1.32	2.295	377.57	4.4	13.97	22.80	14.13
			A	15-45	0.760	1.56	2.32	109.72	13.6	11.38	23.55	11.99
			Bw	45-60	0.526	1.74	2.266	-	-	9.22	17.52	9.87



Pedon 9



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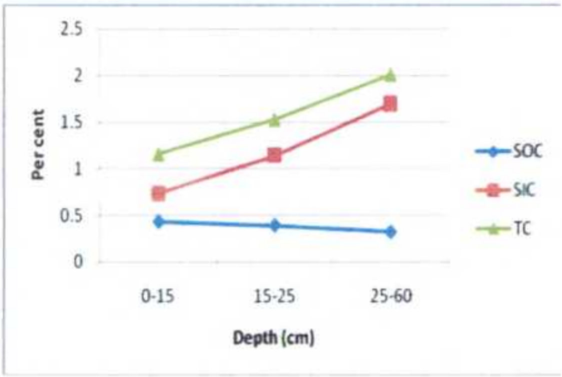
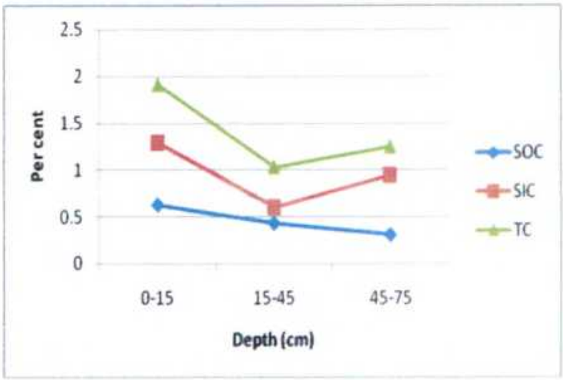


Pedon 13



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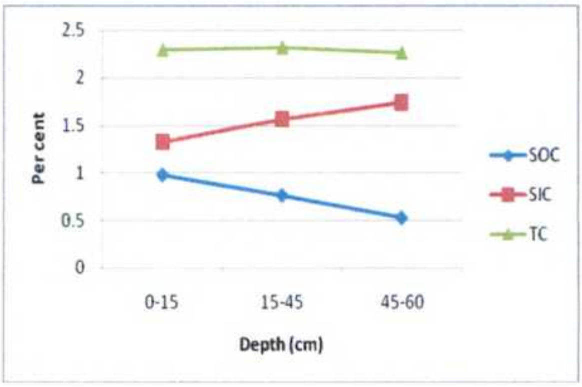


Pedon 10

Fig. 4.9. Depth fraction of SOC, SIC and TC per cent density of Inceptisols of Marathwada

Aurangabad recorded lowest SOC. The association of SOC, SIC and TC content with precipitation and temperature was closest in the top 20 cm of the soil and decrease with depth. In contrast, the correlation between SOC and Clay content was highest in depth of profile. Sand content was negatively correlated with SOC content across all the depth.

While low SOC stock and high SIC stock and the TC stock may be very high. Moreover, in same soils, the SIC may be very less or negligible in the surface soils. It is therefore, Prudent to consider the Soil Organic Carbon (SOC) stock per unit area for identifying systems for better carbon sequestration.

The SMBC was ranged between 109.7 to 744.34 $\mu g\ g^{-1}$. The maximum value was observed in pedon P_{11} (Ausa) Drought prone zone and minimum value in pedon P_{10} (Mandwa) Transitionally high rainfall zone which declines rapidly in increase in depth in most of pedon (Vance., 1987). This generalization is greatly modified by soil texture, mineralogy and land use. Extreme environments generally have low organic matter and very low microbial biomass carbon contents (Table 4.19).

The CO_2 evaluation of Inceptisols was ranged between 2.6 to 13.6 g 100 g hr^{-24} respectively. The higher value was recorded in (P_{10}) Mandwa Bw1 layer Transitionally high rainfall zone and lower value recorded in (P_{12}) surface of Lohagaon profile of Assured rainfall zone. It generally increased in sub surface of all pedons. Because, the soil respiration is basically depends on substrate availability (moisture & temperature).

C:N, C:P and C:S ratios in Inceptisols of Marathwada

The soils of Inceptisols varied in C:N, C:P and C:S ratios from 4.10 to 16.75 , 6.93 to 27.08 and 4.27 to 14.80 with mean values of 8.81, 16.17 and 9.35, respectively (Table 4.19). The highest C:N, C:P and C:S ratios in Inceptisols was found in Ausa pedon at Ap horizon (0-15 cm) in Drought prone zone and lowest value of C:N, C:P and C:S ratios were observed in Aurangabad pedon at Bw horizons (25-45 cm).

4.2.3 Soil Carbon Parameters of Vertisols of Marathwada.

The data presented in Table 4.20 showed that the soil organic carbon, inorganic carbon and total carbon ranged between 0.292 to 1.04, 0.360 to 2.28 and 0.789 to 2.689 per cent, respectively in Vertisol. The SOC, SIC and TC was higher in Drought prone zone compared than Assured rainfall and Moderately with rainfall zone which increased with surface layer and decreased with

Table 4.20. Soil carbon parameters and ratios of Vertisols of Marathwada.

Sr. No	Agro-ecological Zone	Pedon	Horizon	Depth. (cm)	SOC (%)	SIC (%)	TC (%)	SMBC (mg kg^{-1})	CO_2 (mg kg^{-1})	Carbon ratio		
										C:N	C:P	C:S
1	6.1 Drought prone zone	Beed P14	Ap	0-15	0.624	0.492	1.116	294.04	4.4	9.04	16.00	9.20
			A	15-27	0.585	0.420	1.005	120.13	8.8	9.39	15.60	9.60
			Bw	27-60	0.562	1.032	1.594	-	-	10.60	16.02	8.70
			Bssk	60-100	0.331	1.344	1.675	-	-	8.32	23.27	6.20
		Govindpur P17	Ap	0-15	0.994	0.576	1.57	870.23	7.0	16.35	23.66	14.56
			A	15-30	0.624	0.912	1.536	313.70	8.6	10.66	16.97	10.02
			Bw	30-60	0.524	1.08	1.604	-	-	10.43	22.54	8.62
			Bssk	60-105	0.292	1.32	1.612	-	-	6.82	17.68	5.72
		Wadgaon P18	Ap	0-15	0.975	1.14	2.115	404.79	5.7	14.28	23.21	13.97
			A	15-33	0.721	1.32	2.041	208.72	9.1	11.04	25.28	11.71
			Bss1	33-65	0.546	1.896	2.442	-	-	11.93	19.62	9.18
			Bssk	65-100	0.409	2.28	2.689	-	-	9.08	14.34	7.17
		Latur P19	Ap	0-25	0.682	0.336	1.018	669.45	10.0	13.17	23.30	10.32
			Bw1	25-60	0.624	0.456	1.08	786.20	6.8	12.41	19.80	10.27
			Bw2	60-90	0.429	0.360	0.789	-	-	10.03	22.88	7.15
			Bssk	90-120	0.351	0.60	0.951	-	-	12.64	26.00	6.59
		Babulgaon P20	Ap	0-20	1.040	0.576	1.616	747.70	10.0	15.24	24.76	15.24
			Bw1	20-45	0.877	0.48	1.357	620.10	5.3	13.13	24.87	14.25
			Bw2	25-90	0.682	0.78	1.462	-	-	17.82	22.17	11.50
			Bssk	90-110	0.390	1.38	1.77	-	-	11.06	15.75	7.64
2	6.2 Assured Rainfall zone	Bharaswada P16	Ap	0-15	0.741	0.696	1.437	602.49	6.1	13.91	19.37	13.72
			A	15-35	0.641	0.66	1.301	218.51	7.0	13.57	19.00	11.25
			Bw	35-65	0.292	1.380	1.672	-	-	5.98	9.26	5.70
			Bssk	65-102	0.195	2.016	2.211	-	-	4.26	13.00	5.00
		Chudawa P21	Ap	0-13	0.529	1.569	2.098	262.10	10.8	15.20	22.20	11.71
			B	13-32	0.361	1.322	1.683	202.16	6.7	13.11	23.40	11.23
			Bw	32-68	0.218	1.53	1.748	-	-	11.93	18.90	9.40
			Bss	68-100	0.210	1.206	1.416	-	-	9.03	17.20	8.20
		Ranjani P22	Ap	0-15	0.631	1.442	2.073	376.51	8.2	12.18	23.40	10.31
			Bw1	15-35	0.433	1.236	1.669	213.22	10.9	12.03	22.20	10.32
			Bw2	35-70	0.293	1.356	1.649	-	-	10.12	20.13	9.18
			Bssk	70-105	0.202	1.176	1.378	-	-	9.06	18.17	7.80
3	6.3 Moderately high rainfall zone	Hadgaon P15	Ap	0-15	0.624	0.90	1.524	376.90	4.9	9.56	20.29	9.45
			A	15-40	0.507	1.692	2.199	128.17	6.8	8.34	16.09	8.89
			Bw	40-65	0.351	0.936	1.287	-	-	6.50	14.62	6.50
			Bssk	65-105	0.195	2.268	2.463	-	-	4.40	13.00	3.80

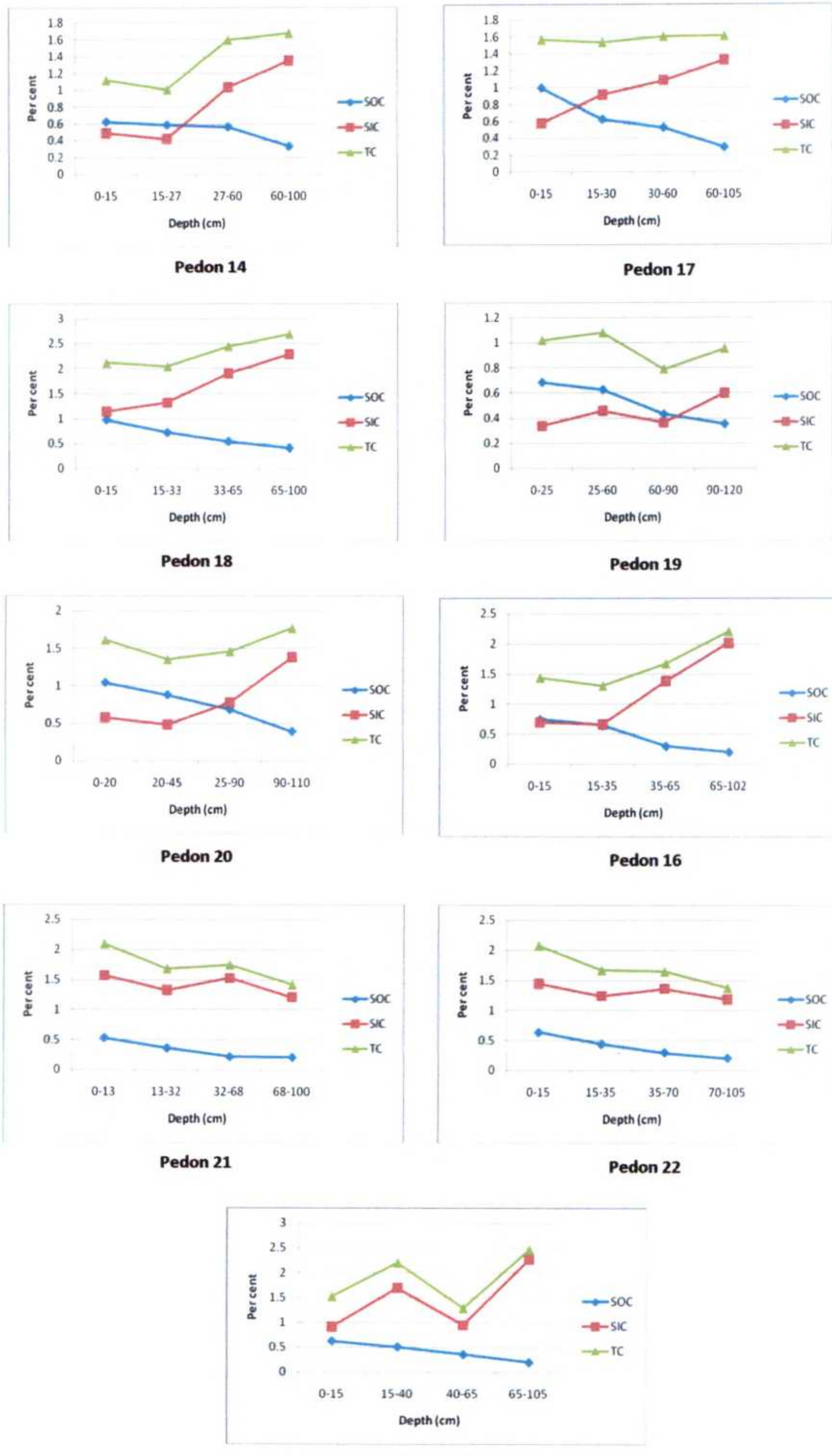


Fig. 4.10. Depth fraction of SOC, SIC and TC per cent density of Vertisols of Marathwada

depth of most pedon. The high SOC value of was recorded 1.04 % in Babhulgaon (P20) and very low value (0.195 per cent) in Hadgaon pedon.

The SOC, SIC and TC stocks is estimated per unit area and is expressed in per cent as presented in table 4.19 and Fig. 4.10. The TC was generally decreased with depth of pedeons. The TC stock depend on the SOC and SIC Stocks; with low SOC stock and high SIC stock, the TC stock may be very high. Moreover, for many soils, the SIC may be nil or negligible in the surface soils.

The Vertisols SMBC was ranged between 120.13 to 786.20 $\mu g\ g^{-1}$. The maximum value was observed in pedon P_{19} (Latur) in Drought prone zone and minimum value in pedon P_{14} (Beed) which declines rapidly in increase of depth in most of pedon (Table 4.20). This generalization is greatly modified by soil texture, mineralogy and land use. Extreme environments generally have low organic matter and very low microbial biomass carbon contents (Table 4.20).

The CO_2 evaluation of Vertisols was ranged between 4.4 to 10.9 100 g^{-1} hr^{-24} respectively. The higher value was recorded in Assured rainfall zone (P_{22}) Ranjni Bw1 layer and lower value recorded in Drought prone zone (P_{14}) Beed surface of profile in generally increases in sub surface of all pedons. Because. The soil respiration is also highly variable may be depending on substrate availability: moisture and temperature.

C:N, C:P and C:S ratios on Vertisols of soils of Marathwada

The C:N, C:P and C:S ratios of Vertisols (Table 4.20) varied from 4.26 to 17.82, 9.26 to 26.00 and 3.80 to 15.24, with their mean values of 10.90, 19.55 and 9.44 respectively (Table 4.20). The highest values of C:N and C:S ratios in Vertisols were found in Drought prone zone of Babulgaon pedon at Bw2 horizon (25-90 cm) and C:S ratio had Ap horizon (0-20 cm) respectively. The highest value of C:P ratios was found in Latur pedon at Bssk horizon (90-120 cm).

The data on the total N, P and S content are given in Appendix-IV. The soils of Vertisols of Marathwada region in Beed,Govindpur and Babhulgaon were also found to contain higher total N due to cultivation of legumes with high levels of management. The high content of total N content could be due to higher application of manures, nitrogenous fertilizers and root biomass of soybean and Pigeon pea which also added considerable amount of organic carbon. This was further evident from positive relationship observed between total N and organic carbon in this agro-ecological zone of Marathwada region. However, the clay content failed to establish any positive relationship with total N content.

Total phosphorus measures the amount of phosphorus tied up in soil mineral particles (which come from the breakdown of rocks) and with organic matter. Total phosphorus is generally much higher than the amount of phosphorus actually available for plant uptake. Unlike nitrogen, phosphorus is involved in geochemical (mineral) reactions that may make phosphorus less available for biotic cycling. Depending upon the parent material and extent of soil weathering, the P content of soil in the world ranges from 0.02 to 0.5%. Variations in total P are mainly due to different parent-rock material types.

Soils with higher phosphorus levels are derived from basaltic rocks because these rocks have higher than- average levels of phosphorus whilst those developed from granite or sandstone have low P. The total P in Indian soils varies from 0.01 to 0.2% with an average of 0.02 to 0.08% for most agricultural soils (Kanwar and Grewal 1974; Khanna and Pathak 1982). The total P content of most Indian soils is low compared to world standards and many soils require phosphate fertilizers to optimize production. Generally, total P is poorly correlated with available P.

The concentration of P in soil solution is very low (0.1 ppm) and since a number of reactions affect availability, P deficiency is a widespread problem in India. As an example, the unweathered calcareous soils of dry regions often have high P content due to general lack of leaching and the presence of appreciable amounts of P in the form of apatite. The P content of many soils has been altered by cropping, addition of animal manures and fertilizers. Thus, high amounts of P in the parent material and the relatively low amounts in the profile suggest that losses through leaching were extensive during weathering and soil formation, which provides more information to aid in phosphorus management and carbon sequestration in dryland soils.

Thus, characterization of total P in surface layers of semi-arid tropical (SAT) soils of India can be used to identify areas where natural soil fertility is low and fertilizer inputs would be required for maximum root and shoot biomass and for increased organic matter content and thus for enhanced carbon sequestration in these soils. This section focuses on the variations in the content of total soil P as influenced by climate and its relationships with organic carbon other soil properties. The total P content of Indian semi and tropical soils ranged from 0.014 to 0.186 % (per cent by weight). In Vertisols the total S content highest may be under high management system with cotton, soybean and pigeon pea rotation recorded highest total and available S content.

4.2.4 Agro-ecological zone wise Organic carbon status of Marathwada

Table 4.20a. Organic carbon status of varied Agro-ecological zones of Marathwada

Sr. No.	Zone No.	SOC (%)	SIC (%)	TC (%)	SMBC ($\mu g\ kg^{-1}$)	CO_2 (mg CO_2 kg^{-1} 24 hr^{-1})
1	6.3	0.720	0.972	1.692	431.09	7.94
2	6.2	0.624	1.462	2.026	413.74	6.76
3	6.1	0.614	0.90	1.524	376.90	5.9
4	6.4	0.760	1.136	1.896	411.55	7.3

(Values are means of 15 cm of each surface Pedon)

The organic carbon status of four (4) Agro-ecological zones observed in Marathwada region of Maharashtra state in presented in Table 4.20a. The data reviled that Agro-ecological zone 6.1 (drought per zone) shoed low soil organic carbon (0.61 per cent) as compared to other agro-ecology zones. It was recorded that with increased in the arrival rainfall the soil organic carbon percentage was increased. The average soil organic carbon percentage was recorded in Agro-ecology zone 6.2, 6.3 and 6.4 was 0.61, 0.720 and 0.780 per cent respectively.

The soil inorganic carbon percentage have not show any specific pattern with rainfall the zones. The maximum soil inorganic carbon was found in assigned rainfall zone 6.2 (1.462 per cent), followed by transitionally high rainfall zone (1.136 per cent).

The total carbon was minimum in Agro-ecology zone 6.1 (1.524) followed by the maximum total carbon was recorded in Agro-ecology zone 6.2 followed by Agro-ecology zone 6.4 and Agro-ecology zone 6.3.

4.2.5 Soil organic carbon status of various soil types of Marathwada

Table 4.20b . Soil type wise Organic carbon status of Marathwada

Sr. No.	Soil Orders	SOC (%)	SIC (%)	TC (%)	SMBC ($\mu g\ kg^{-1}$)	CO_2 (mg CO_2 kg^{-1} 24 hr^{-1})
1	Entosols	1.830	2.759	4.88	1094.21	14.40
2	Inceptisols	2.246	5.698	7.944	1387.84	27.64
3	Vertisols	2.112	3.918	5.412	1223.18	20.62

(Values are means of 15 cm surface soil samples of each Pedon)

Among three (3) soil types of Entisol, Inceptisol and Vertisols observed in Marathwada region, Inceptisols showed maximum SOC, SIC, TC, SMBC and CO_2 values followed by Vertisols and Entisols (Table 4.20b).

4.3 SOIL ORGANIC CARBON MAPPING OF MARATHAWADA.

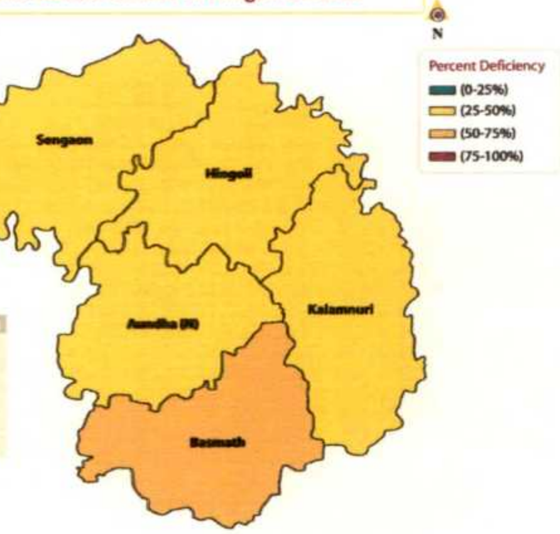
The soil organic carbon mapping was brought out by the ratings provided by Parker (1951). So as to prepare maps the data were collected and used from 22 soil profile representing important soil series of the region of Marathawada. Three hundred thirty surface soil samples collected from adjoining areas of the location of soil profiles. Further additional data from the government soil testing laboratory were also used for mapping. The map ware prepared by using Coral Drow 14.3 and Photoshop.

The eight districts of region of Marathwada are represented by the four agro-ecological regions *viz.* Drought Prone zone 6.1, Assured rainfall zone 6.2, Moderately higher rainfall zone 6.3 and Transistionally high rainfall zone 6.4. However for the easiness and understanding soil organic carbon status maps were shown district wise.

4.3.1 Organic carbon status of Hingoli district

Percent deficiency of organic carbon shown in map (Fig. 4.11) indicated that out of five tehsils of Hingoli, Basmat tehsil soil found to be more defficient. Nearly 67 per cent soils appeared to deficient in organic carbon Followed by Sengaon tehsils (48%) Aundha and Kamulnari (39 each) and Hingoli (37 per cent).

Fig.4.11 Organic Carbon Status of Hingoli District



Talukawise Org.Carbon Deficiency (%)	
Aundha (N)	39
Basmath	67
Hingoli	37
Kalamnuri	39
Sengoan	48
Average	46

4.3.2 Organic carbon status of Nanded district

Fig 4.12 shows the organic carbon status of Nanded District. It was observed that about 25 to 50 Percent soils of four tehsils viz Kandhar, Ardhapur, Bhokar, and Kinvat found deficient in organic carbon. While in rest twelve tehsil the deficiency of organic carbon was to the tune of 51 to 75 per cent. The average deficiency of organic carbon was to the extent of 52.60 per cent in Nanded district.

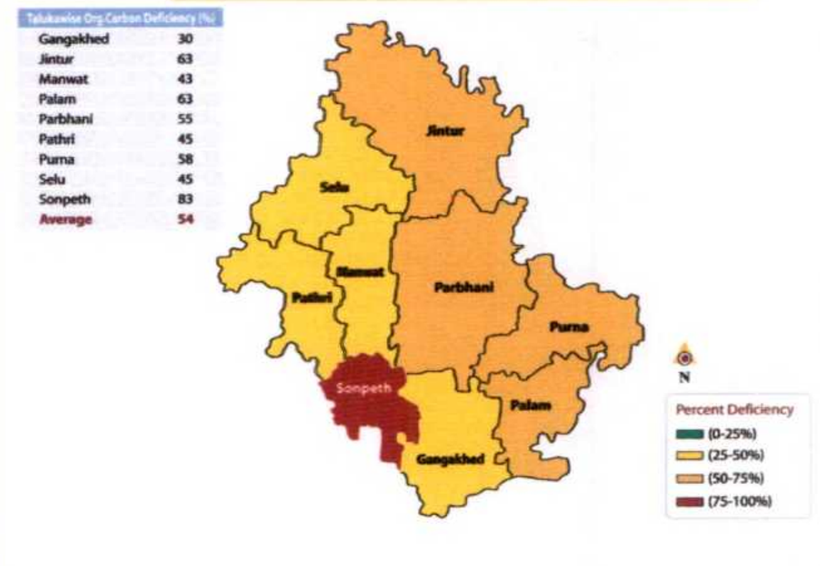
Fig.4.12 Organic Carbon Status of Nanded District

Talukawise Org.Carbon Deficiency (%)	
Mudkhed	57
Ardhapur	50
Dharmabad	54
Naigaon	50
Loha	55
Umri	55
Kandhar	49
Kinwat	50
Bhokar	50
Mahur	53
Mukhed	56
Degloor	52
Himayatnagar	51
Biloli	53
Nanded	55
Hadgaon	52
Average	52.60

4.3.3 Organic carbon status of Parbhani district.

The organic carbon deficiency in Parbhnai was spread over an area of 54 per cent. It was minimum in Gangakhed (30 %) and maximum in Sonpeth tehsil (Fig. 4.13).

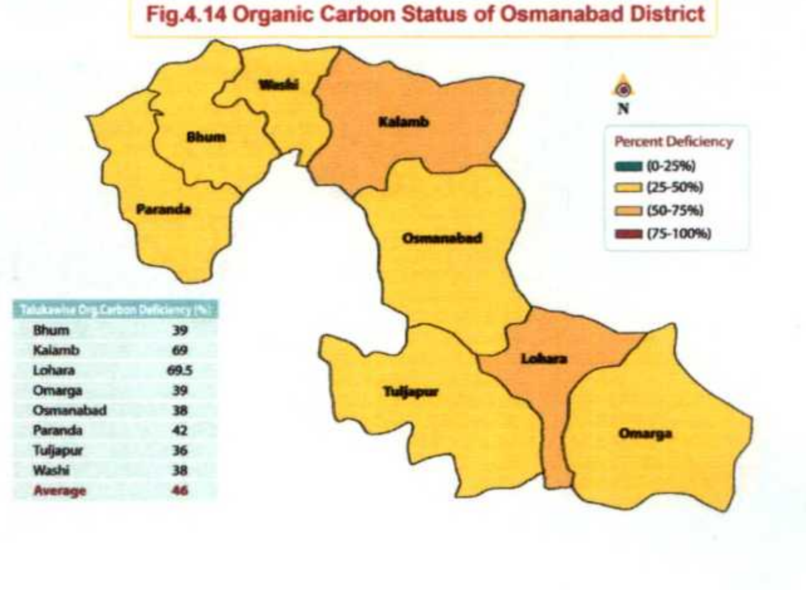
Fig.4.13 Organic Carbon Status of Parbhani District



4.4.4 Organic carbon status of Osmanabad district.

On an average 46 per cent soils of Osmanabad District are low in organic carbon. Amongst the eight tehsils, the Kalamb and Lohara Tehsils showed higher deficiency than rest of the tehsils in Osmanabad district (Fig. 4.14).

Fig.4.14 Organic Carbon Status of Osmanabad District



4.3.5 Organic carbon status of Jalna district

Sixty seven percent soils of Jalna district showed low organic carbon status. Out of eight tehsils of Jalna 76 per cent soil of Ambad tehsil found deficient followed by Badnapur and Jafrabad (Fig. 4.15).

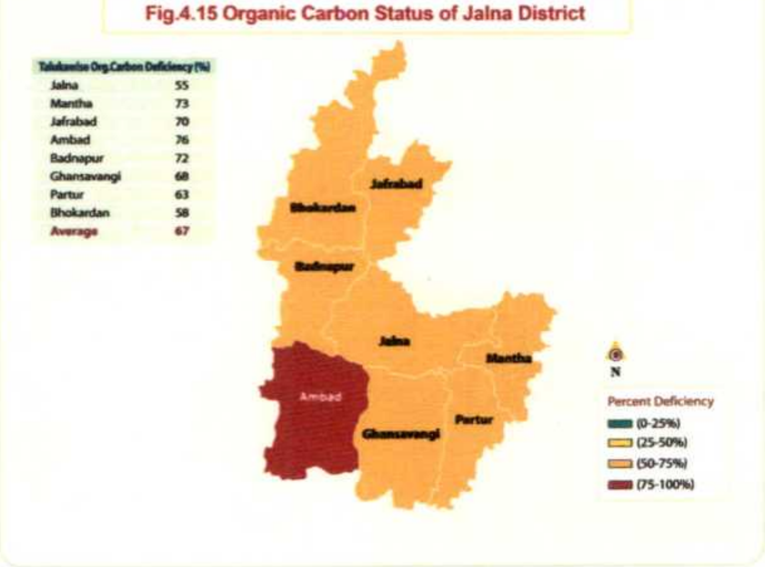


Fig.4.15 Organic Carbon Status of Jalna District

4.3.6 Organic carbon status of Beed distric

The wide variation of organic carbon status was noticed in Beed district. Almost all soils of Ambajogai tehsils were low in organic carbon followed by Kej (90 %) and Parli (80 %). The Shirur Kasar soil found relatively better in organic carbon status, because about 30 percent soils showed low organic carbon (Fig. 4.16).

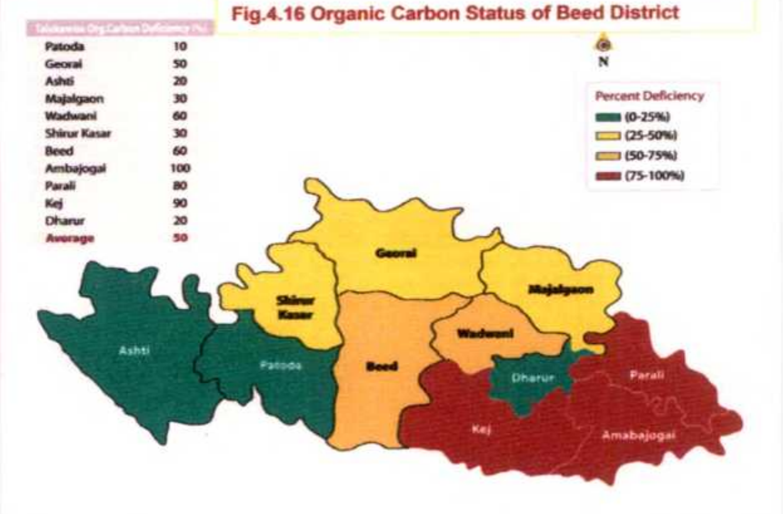


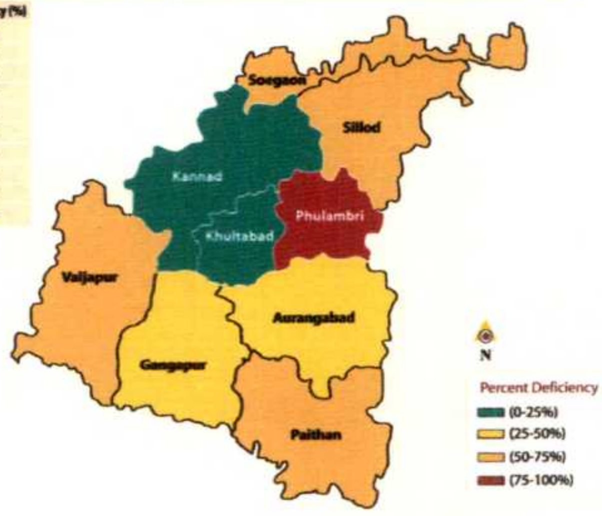
Fig.4.16 Organic Carbon Status of Beed District

4.3.7 Organic carbon status of Aurangabad district.

The organic carbon deficiency was at lower on magnitude in the soils of Khultabad and Kannad tehsils. Which 86 per cent area of Phulambri tehsil showed low organic carbon status. In general (50 %) area of Aurangabad showed low organic carbon status(Fig 4.17).

Fig.4.17 Organic Carbon Status of Aurangabad District

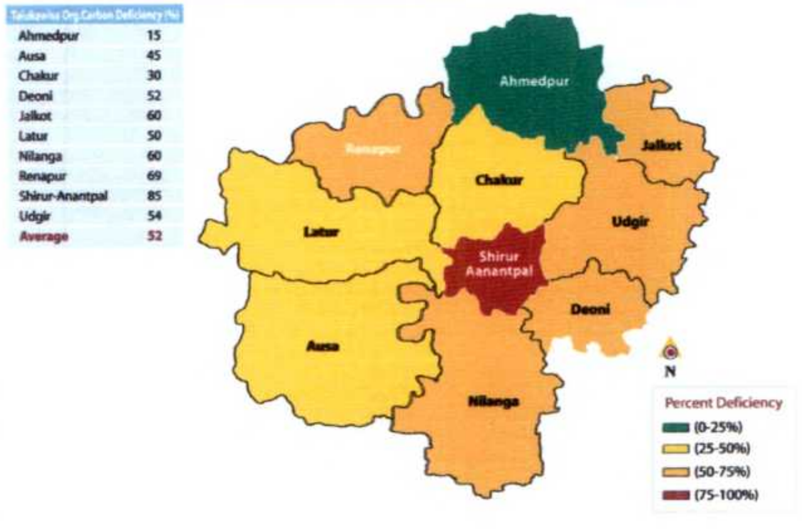
Talukawise Org.Carbon Deficiency (%)	
Gangapur	31
Phulambri	86
Vaijapur	59
Khultabad	22
Paithan	71
Aurangabad	28
Kannad	25
Soegaon	66
Sillod	60
Average	50



4.3.8 Organic carbon status of Latur district.

From the Figure 4.18 it is evidenced that Shirur Anantpal tehsil is more affected due organic carbon deficiency (85%). while only 50 % area of Ahamedpur showed low organic carbon status. On an average the organic carbon deficiency was spread over an area of 52 percent.

Fig.4.18 Organic Carbon Status of Latur District



From the result depicted through various organic carbon maps, it is inferred that the soils of Marathawada are badly affected due to low organic carbon content. The organic carbon deficiency was spread over 46 % area of Hingoli district, 52 % area of Nanded district, 52 % area of Parbhani district, 46 % area of Osmanabad district, 67% area of Jalna district, 58% area of Beed district, 50% area of Aurangabad district and 52% area of Latur district. This clearly shows that almost 50% soils of Marathawada soils had less than 0.5 per cent organic carbon. It is interesting to note that the tehsil which has more barren/uncultivated area or single cropped (Only *Kharif*) showed high organic carbon status. e.g. Kannad, Khultabad tehsils of Aurangabad, Ahamedpur tehsil of Latur, Ashati, Patoda and Dharur tehsil of Beed. The intensively cropped area of more spread had organic carbon deficiency.

This might be because of higher rate of oxidation of organic carbon in intensively cropped area because of intensive cultivation. This clearly emphasizes that for conservation of soil carbon minimum cultivation is required.

From these maps it was also inferred that ecology of the region play important role in organic carbon status. The area receiving higher rainfall showed more organic carbon in the virgin areas.

These maps generated in present investigation will be of useful for better understanding and developing a tehsil wise crop production and fertility management technology.

The attestation must be paid toward the building up of organic carbon status while planning the agril. production technology programs. This will definitely help in brining out the sustainable crop productivity and nature conservation.

Table 4.21. Correlation ('r' values) coefficients between pH, EC, $CaCO_3$, and soil organic carbon with its carbon parameters.

	SOC	SIC	TC	CO_2	SMBC	C:N	C:P	C:S
Entisols								
pH	-0.485*	-0.475*	0.481*	-0.490*	-0.480*	-0.461*	-0.166	-0.507*
EC	-0.505*	0.048	-0.260	0.334	-0.140	-0.420	-0.540*	-0.472*
$CaCO_3$	-0.739**	-0.768**	0.504*	-0.421*	-0.560*	-0.466*	-0.592**	-0.534*
Inceptisols								
pH	-0.525*	-0.524*	-0.555*	-0.568*	-0.589*	-0.557*	-0.543*	-0.575*
EC	0.032	-0.159	-0.116	-0.524*	-0.639**	0.177	0.268	0.191
$CaCO_3$	-0.542*	0.949**	0.843**	-0.562*	-0.554*	-0.506*	-0.506*	0.563*
Vertisols								
pH	-0.345*	-0.404*	-0.392*	-0.499**	-0.380*	-0.498**	0.488**	-0.342*
EC	-0.512**	0.181	0.013	0.022	-0.127	-0.328*	-0.106	-0.256
$CaCO_3$	-0.488**	0.973**	0.838**	0.227	-0.580**	-0.482**	-0.408*	-0.479**

	Entisol	Inceptisol	Vertisol
* Significant at the 0.5% level	0.468	0.482	0.324
** Significant at the 0.01% level	0.589	0.605	0.418

4.3.9 Correlation coefficient between physico-chemical properties with soil carbon parameters

Correlation studies were carried out to understand the dependency of carbon parameters in relation to soil properties. The results obtained on soil properties and soil carbon parameters were subjected to the simple correlation and the values are presented in table 4.21.

4.3.9.1 Entisols

The data on correlation coefficient between physico-chemical properties and soil carbon parameters of Entisols of Marathwada region are presented in table 4.21. From these results, it was observed that soil organic carbon significantly affected by pH, EC and $CaCO_3$ content. The pH was found to bear negative relationship with soil organic carbon (r = 485*), SIC (r = -0.475*), TC (r = 481*), CO_2 (r = -4.290*), SMBC (r = -0.480*), C:N ratio (r = -0.461*) and C:S ratio (r = 5.07*). The significant negative relationship with EC was evident from 'r' values (-0.505*, -0.540* and -0.472*) was observed between SOC, C:P ratio and C:S ratio. Similarly, $CaCO_3$ showed negative and significant correlation with carbon parameters live SOC (-0.739**), SIC (-0.768**), TC (-0.504*), CO2 (-0.421*), SMBC (-0.560*), C:N ratio (-0.466*), C:P ratio (-0.592**) and C:S ratio (-0.534*).

4.3.9.2 Inceptisols

The data on correlation coefficient between physico-chemical properties and carbon parameters of Inceptisols of Marathwada region are presented in table 4.21. In Inceptisols, various carbon parameters are also found to be influenced by physico-chemical properties. Significant negative relationship with pH and $CaCO_3$ was recorded between pH and SOC, SIC, TC, CO_2, SMBC, C:N ratio, C:P ratio and C:S ratio and in between $CaCO_3$ and SOC, SIC, TC, CO_2, SMBC, C:N ratio, C:P ratio and C:S ratio, (-0.525*, -0.524*, -0.555**, -0.568*, -0.589*, -0.557*, -0.543* and -0.575 and -0.542*, 0.949**, 0.843**, -0.562*, -0.554*, -0.506*, -0.506* and -0.563*) respectively. Electrical conductivity of these soil order showed significant negative relationship with CO_2 evolution (-0.524*) and SMBC (-0.639**).

4.3.9.3 Vertisols

The data on correlation coefficient between physico-chemical properties and carbon parameters of Vertisols of Marathwada region are presented in table 4.21. The various carbon parameters found to be influenced by physico-chemical properties of Vertisols. pH and $CaCO_3$ content were found to bear negative relation with SOC, SIC, TC, CO_2, SMBC, C:N ratio, C:P ratio and C:S ratio. Negative 'r' values of -0.345*, -0.404*, -0.392*, -0.499*, -0.380*, -0.498, -0.488** and -0.342* are noticed between pH and SOC, SIC, TC, CO_2, SMBC, C:N ratio, C:P ratio and C:S ratio, respectively. Significant and negative relationship with $CaCO_3$ content was recorded for SOC (-0.488**), SIC (-0.973**), TC (-0.838**), SMBC (-0.580**), C:N ratio (-0.482*), C:P ratio (-0.408*) and C:S ratio (-0.479**). Further, electrical conductivity also showed negative and significant relationship with SOC (-0.512**) and C:N ratio (-0.328*).

Thus, it was noted from above results that the carbon parameters established that the negative and significant correlation with pH and EC. High pH decreased the pool of total, organic and inorganic carbon in soil. Similarly negative relationship between $CaCO_3$ and carbon parameters may be because of to calcium carbonate might have acted as a strong adsorbent of carbon fractions and resulted into low solubility if nutrients. Similar results were reported by Kadu (1993) and Patil (2010).

4.4 SOIL SITE SUITABILITY AND LAND USE PLANNING

Cropping pattern and land use have always been part of the evolution of human society. The function of the land use planning is to guide such a way that the resources of the environment were put to the most beneficial use for man, this planning based on an understanding both of the natural environment and of the kind of land use envisaged. It also involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative form of land use.

Table 4.24. Climatic characteristics of crops like soybean, pigeonpea and cotton in Marathwada region.

Characteristics	Crops		
	Soybean	Pigeonpea	Cotton
Total rainfall (mm)	800-1200	1000-850	850-1050
Rainfall during growing season (mm)	700-800	850-750	750-950
Mean minimum temperature during growing season (^{0}C)	21-27	26-24	28-32
Mean maximum temperature during growing season (^{0}C)	27-30	32-28	-
Mean relative humidity in growing season (%)	>80	-	80-90
Length of growing period	100-120	150-180	160-180

Every plant species need specific soil-site conditions for its optimum growth and yield, imperative to use the finite soil resource according to its capability or suitability for particular land use. This can be achieved by Agro-ecologically zone and critically evaluating the soil-site conditions vis-à-vis specific climatic characteristics of different crops (Table 4.25 to 4.27).

The literature on specific crop requirement forms an important part of the suitability evaluation. The of information on the crops under study have been adopted from the proceeding of the National Meet on soil site suitability criteria for different crops recognized at the National Bureau of Soil Survey and Land Use Planning, Nagpur (NBBS and LUP 1994) The suggested soil site

Table 4.25 Soil Site characteristics of Entisols of Marathwada region of Maharashtra.

Soil Site Characteristics	Vajapur Pedon-1	Kej Pedon-2	Kinwat Pedon-3	Rohadi Pedon-4	Tar Pedon-5	A.pur Pedon-6	L. tanda Pedon-7	Dahasadi Pedon-8
Slope %	3-4	1-3	5-8	1-3	2-3	2-3	1-3	1-2
Hydraulic conductivity (mm ha^{-1})*	2	1.8	7.4	4.4	2.2	1.5	1.7	3.8
Drainage	Well	Well	Well	M.Well	Well	Well	Well	M Well
Soil Characteristics								
Texture*	sl, cl	sl	sl	cl	scl	scl	sl	scl
Depth (cm)	28	27	20	26	20	25	30	26
Soil Fertility								
$CaCo_{3*}$	10.6	12.0	6.0	14.8	11.1	15.0	11.1	12.1
Organic carbon (g)*	5.7	7.9	9.3	3.8	5.7	4.7	7.7	4.8
EC (dsm^{-1})*	0.759	0.222	0.184	0.532	0.297	0.366	0.134	1.4
pH (1:2)*	7.8	7.4	6.6	7.3	8.0	8.1	8.3	8.6
CEC (Soil) [Cmol (p^{+}) kg^{-1}]*	54.6	66.8	61.15	52.15	52.3	67.0	38.35	45.2

*Weighted mean (WM) of 0-28 cm depth on Entisols

Table 4.26. Soil Site characteristics of Inceptisols of Marathwada region of Maharashtra.

Soil Site Characteristics	**A'bad Pedon 9**	**Mandawa Pedon 10**	**Ausa Pedon 11**	**Lohagaon Pedon 12**	**Gevrai Pedon 13**
Slope %	1-2	1-3	1-3	1-3	3-5
Hydraulic conductivity (mm ha^{-1})*	2.1	1.4	2.2	1.9	1.7
Drainage	M.Well	M.Well	Well	Well	Well
Soil Characteristics					
Texture*	c	c	cl	c	cl
Depth (cm)	75	60	75	75	60
Soil Fertility					
$CaCo_{3*}$	17.2	12.9	11.4	6.3	9.9
Organic carbon (g)*	3.83	7.53	5.74	4.57	3.79
EC (dsm^{-1})*	0.304	0.384	0.862	1.443	0.249
pH (1:2)*	8.13	7.83	8.0	8.16	8.13
CEC (Soil)[Cmol (p^{+}) kg^{-1}]*	52.2	47.0	52.2	46.5	52.3

*Weighted mean (WM) of 0-70 cm depth on Inceptisols

Table 4.27. Soil site characteristic on Vertisols of Marathwada region of Maharashtra.

Soil Site Characteristics	Beed Pedon 14	Hadgaon Pedon 15	Bharaswada Pedon 16	Govindpur Pedon 17	Wadgaon Pedon 18	Latur Pedon 19	Babulgaon Pedon 20	Chudawa Pedon 21	Ranjani Pedon 22
Slope %	1-3	0-3	1-3	2-3	1-3	1-3	1-3	1-2	1-3
Hydraulic conductivity (mm ha^{-1})*	1.6	0.95	1.15	3.2	2.4	4.4	0.9	1.2	1.4
Drainage	M. Well	Imperfect	M. Well	M. Well	Imperfect	M. Well	Imperfect	M. Well	M. Well
Soil Characteristics									
Texture*	c	c	c	c	c	c,cl	c	c	c
Depth (cm)	100	105	102	105	100	120	110	110	105
Soil Fertility									
$CaCo_3^*$	6.85	12.07	9.9	8.1	13.8	3.6	8.1	8.2	7.2
Organic carbon (g)*	5.25	4.19	4.6	4.5	6.62	5.21	7.37	6.21	5.62
EC (dsm^{-1})*	0.262	0.567	0.237	0.362	0.249	0.315	0.283	0.521	0.422
pH (1:2)*	7.75	8.5	8.1	8.3	7.97	8.17	8.15	8.4	8.3
CEC (Soil) [Cmol (p^+) kg^{-1}]*	60.6	49.3	52.12	46.35	49.25	52.72	75.00	54.3	52.1

*Weighted mean (WM) of 0-120 cm depth on Vertisols suitability criteria considered as a base was modified and refined keeping into account the local conditions (Table 4.23).

The existing soil- site condition (Table 4.25, 4.26 and 4.27) were compared with the criteria of each crop and based on the number of intensity of limitation. The overall suitability was determined as suggested by Sys (1985), Sys *et al.* (1991), the method defined, land classes with regard to number and intensity of limitations. The criteria of limitation method as given by Sys *et al.* (1991) is slightly modified because of the increased number of parameter in the parent study for the suitability evaluation and given below:

Class S1 (Highly suitable)	Land unit with nil. or up to 5 slight limitation
Class S2 (Moderately suitable)	Land units with more than 5 slight limitation and / or no more than two severe limitation.
Class S3 (Marginally suitable)	Land unit with more than 4 moderate limitation or/ and no more than two sever limitations.
N1 (Currently not suitable)	Land unit with more than 2 severe limitation that can be corrected.
N2 (Unsuitable)	Land units having very severe limitation that cannot be corrected.

In addition, the suitability classes were also based on the actual yield as suggested by FAO (1983) This was based on the yield levels for the suitability classes as S1 > 80 %, S2 40% to 80 %, S3 20 to 40% and N< 20% . The yield reduction levels have been decided on the optimum yield of the crop. The optimum yield was calculated with the help of data collected from 10 farmer fields with similar management practices and the average of 2 to 4 commercial varieties grown in the soils of the Marathwada region.

4.4.1 Soil- site suitability evaluation for soybean.

Soybean is the most important pulse as well as oilseeds crop the Marathwada region and a cash crop with low cost benefit ratio. The commercially growing variety in the study area, such as PK-472, JS-335, PKV-1 and KL-441 The soil -site requirement given for soybean crop (NBSS and LUP, 1994). The Entisols of Lithic Ustorthents pedon Agro ecological zone of 6.1-Drought prone zone-pedon P1, P2, P5, P6 and P7. 6.2-Assured Rainfall zone pedon-P8 and 6.4-Transitionally high rainfall zone were unsuitable (N2) and Typic Ustochrepts (Inceptisols) pedon of 6.1- Drought prone zone P9, P11 and P13. 6.2-Assured Rainfall zone Pedon P12 and Transitionally high rainfall zone pedon 10 are moderately suitable (S2) Pedon 9, 20,11 and 13 were marginally suitable (S3) for soybean (Table 4.31 and Table 4.32). The soils of Vertisols Typic Haplusterts Pedon Agroecological zone of 6.1-Assured Rainfall zone-P16, P21, P14 and P20. 6.2- Assured Rainfall zone-P16, P21, and P22 and 6.3- Moderately high rainfall zone- Pedon-P15 was marginally suitable (S_3) were observed in Pedon 22 (Ranjani) and P14, 15, 19, 21 and 22 had Moderately suitable (S3) and P6, P7 and P8 were moderately suitable for soybean crop soils of Inceptisols (Typic Ustochrets) pedon P13 were Marginally and Suitable (S3) & moderately suitable (S2) other all pedons.

The soils of Vertisols (Typic Haplusterts) Pedon 20, 19 and 16 was highly suitable for soybean crop (Table 4.32).

4.4.2 Soil site suitability for Pigeon pea.

Pigeon pea is the most important pluse crop in this area. The commercial variety grown in this area *viz.*, BSMR-736, BDN-1, and BSMR-853.

Pigeon pea is the long duration crop it need the availability of moisture for longer period. Typic Ustochrepts fulfill these requirements and therefore are moderately suitable (S2) for pigeonpea crop. (Table 4.28)

The soils of under Agro-ecological region Inceptisols (Typic ustochrepts) Pedon P10, P11, P12 and P13 are Unsuitable (N2) of where as soils of Typic Haplusters Pedon P14, 15 and 22 were marginally suitable (S3) and Pedon 17, and 21 was moderately suitable for pigeonpea crop (Table 34,35).

According to FAO (1983), the suitability of pigeon peon crop on the basis of optimum yield level (20.00 g ha^{-1}) the soils of Typic Haplusters (Vertisols) were highest suitable (S1) and Typic Ustochrepts were Moderately suitable (S2) for pigeonpea.

4.4.3 Soil Site suitability for Cotton.

Cotton is an important cash crop grown widely in the study area. It may be successfully grown under atmospheric temperature 21 to 27 ^{0}C during growing season and in a rainfall of 500 to 1000 mm. It may be grown on soils with texture from loamy sand to clays (smectitic), but most suitable are loamy to clayey soils (Sys *et al.*, 1993). Since cotton has deep rooting system, the maximum yield is obtained in soils having 200 mm or more plant available water capacity. For successful growth of cotton, a soil depth of 100-200 cm has been observed to be optimum while less then 100 cm is not economical for good growth of cotton (Sehgal, 1991).

The Vertisols of Typic Haplusterts pedon P15, P16, P17, P21 and P22 was marginally suitable (S3) and P14, P18, P19 and P20 were moderately suitable (S2) for cotton (Table 4.31). But according to FAO (1983) the suitability based on optimum yield basis the soil Typic Haplustert Pedon P16 and P19 was highly suitable for cotton crop.

Table 4.28. Degree and kind of major constraints, suitability and yield of Soybean in Entisols of Marathwada.

Pedon No.	Quality parameter or contents											
	LGP	Slope	Depth	Texture	SHC	$CaCo_3$	EC	pH	O.C.	Suitability class	Yield Q/ha	% yield to optimum	Suitability based on actual yield
Pedon 1	--	--	****	*	*	**	*	*	*	N2	7.28	29.12	S3
Pedon2	--	*	****	**	*	**	*	*	*	N2	7.65	30.6	S3
Pedon3	--	--	****	**	***	*	*	*	**	N2	--	--	Forest land
Pedon4	--	*	****	*	***	**	*	*	*	N2	7.14	28.56	S3
Pedon5	--	*	****	*	*	**	*	**	*	N2	7.54	30.16	S3
Pedon6	--	*	***	*	*	**	*	**	***	S3	10.1	40.4	S2
Pedon7	--	*	***	**	*	**	*	**	***	S3	11.5	44.8	S2
Pedon8	--	*	***	*	*	**	*	***	***	S3	12.3	49.2	S2

* Based on maximum observed yield as optimum : 25 q/ha (mean of 10 farmers) limitation – No. *Slight, ** Moderate, *** Severe, **** Very severe.

Table 4.29. Degree and kind of major constraints, suitability and yield of Pigeon pea in Inceptisols of Marathwada.

Pedon No.	Quality parameter or contents											
	LGP	Slope	Depth	Texture	SHC	$CaCo_3$	EC	pH	O.C.	Suitability class	Yield Q/ha	% yield to optimum	Suitability based on actual yield
Pedon 9	--	*	**	*	*	**	*	*	**	S2	1134.8	56.7	S2
Pedon 10	--	*	***	*	*	**	*	*	*	S2	891.3	44.5	S2
Pedon 11	--	*	**	**	**	**	*	*	*	S2	980.5	49.0	S2
Pedon 12	--	*	**	*	*	*	*	*	**	S2	867.5	43.3	S2
Pedon 13	--	**	***	**	*	*	*	*	**	S2	790.5	39.5	S3

* Based on maximum observed yield as optimum : 20 q/ha (mean of 10 farmers) limitation – No. *Slight, ** Moderate, *** Severe, **** Very severe.

Table 4.30. Degree and kind of major constraints, suitability and yield of Soybean in Inceptisols of Marathwada.

Pedon No.	Quality parameter or contents												
	LGP	Slope	Depth	Texture	SHC	$CaCo_3$	EC	pH	O.C.	Suitability class	Yield Q/ha	% yield to optimum	Suitability based on actual yield
Pedon 9	--	*	**	*	*	**	*	*	**	-	-	-	No sowing
Pedon 10	--	*	***	*	*	**	*	*	*	S3	13.4	53.6	S3
Pedon 11	--	*	**	**	**	**	*	*	*	S2	14.2	56.8	S3
Pedon 12	--	*	**	*	*	*	*	*	**	S2	16.5	66.00	S2
Pedon 13	--	**	***	**	*	*	*	*	**	S3	12.4	49.6	S3

* Based on maximum observed yield as optimum : 25 q/ha (mean of 10 farmers) limitation – No. *Slight, ** Moderate, *** Severe, **** Very severe.

Table 4.31. Degree and kind of major constraints, suitability and yield of Cotton in Vertisols of Marathwada.

Pedon No.	Quality parameter or contents												
	LGP	Slope	Depth	Texture	SHC	$CaCo_3$	EC	pH	O.C.	Suitability class	Yield Q/ha	% yield to optimum	Suitability based on actual yield
Pedon 14	--	*	*	*	**	*	*	*	**	S2	10.53	42.12	S2
Pedon 15	--	*	*	*	**	**	*	**	***	S2	11.04	44	S2
Pedon 16	--	*	*	*	**	*	*	*	***	S2	19.87	79.5	S1
Pedon 17	--	*	*	*	*	*	*	*	***	S2	15.48	62	S2
Pedon 18	--	*	*	*	*	**	*	*	**	S1	--	--	No Sowing
Pedon 19	--	*	*	*	*	*	*	*	**	S1	13.48	53.5	S2
Pedon 20	--	*	*	*	**	*	*	*	**	S1	19.85	79.5	S1
Pedon 21	--	*	*	*	*	*	*	*	**	S1	13.48	53.9	S2
Pedon 22	--	*	*	*	*	*	*	*	**	S2	13.01	52.04	S2

* Based on maximum observed yield as optimum : 25 q/ha (mean of 10 farmers) limitation – No. *Slight, ** Moderate, *** Severe, **** Very severe.

Table 4.32. Degree and kind of major constraints, suitability and yield of Soybean in Vertisols of Marathwada.

Pedon No.	Quality parameter or contents												
	LGP	Slope	Depth	Texture	SHC	$CaCo_3$	EC	pH	O.C.	Suitability class	Yield Q/ha	% yield to optimum	Suitability based on actual yield
Pedon 14	--	*	*	*	**	*	*	*	**	S2	13.2	52.8	S2
Pedon 15	--	*	*	*	**	**	*	**	***	S3	14.8	59.2	S2
Pedon 16	--	*	*	*	**	*	*	*	***	S3	21.2	84.8	S1
Pedon 17	--	*	*	*	*	*	*	*	***	S3	18.6	74.4	S2
Pedon 18	--	*	*	*	*	**	*	*	**	S2	--	--	S2
Pedon 19	--	*	*	*	*	*	*	*	**	S2	17.21	68.84	S2
Pedon 20	--	*	*	*	**	*	*	*	**	S2	23.5	94.0	S1
Pedon 21	--	*	*	*	*	*	*	*	**	S2	16.3	65.2	S2
Pedon 22	--	*	*	*	*	*	*	*	**	S2	15.2	60.8	S2

* Based on maximum observed yield as optimum : 25 q/ha (mean of 10 farmers) limitation – No. *Slight, ** Moderate, *** Severe, **** Very severe.

Table 4.33. Degree and kind of major constraints, suitability and yield of Pigeon pea in Vertisols of Marathwada.

Pedon No.	Quality parameter or contents												
	LGP	Slope	Depth	Texture	SHC	$CaCO_3$	EC	pH	O.C.	Suitability class	Yield Q/ha	% yield to optimum	Suitability based on actual yield
Pedon 14	--	*	*	*	**	*	*	*	**	S2	11.2	56.0	S2
Pedon 15	--	*	*	*	**	**	*	**	***	S3	11.9	59.5	S2
Pedon 16	--	*	*	*	**	*	*	*	***	S3	16.9	84.5	S1
Pedon 17	--	*	*	*	*	*	*	*	***	S3	15.2	76.0	S2
Pedon 18	--	*	*	*	*	**	*	*	**	S2	--	--	S2
Pedon 19	--	*	*	*	*	*	*	*	**	S2	14.8	74.0	S2
Pedon 20	--	*	*	*	**	*	*	*	**	S2	18.5	92.5	S1
Pedon 21	--	*	*	*	*	*	*	*	**	S2	13.9	69.5	S2
Pedon 22	--	*	*	*	*	*	*	*	**	S2	12.52	62.6	S2

* Based on maximum observed yield as optimum : 20 q/ha (mean of 10 farmers) limitation – No. *Slight, ** Moderate, *** Severe, **** Very severe.

SUMMARY AND CONCLUSION

Chapter V

SUMMARY AND CONCLUSIONS

The present investigation "Organic carbon mapping of Agro-ecological zones of Marathwada region of Maharashtra state" was carried out during 2009 to 2012 as a Ph.D. research programme.

A comprehensive study encompassing 22 soil profiles (Identified soils series) and 330 surface soil samples were evaluated for various soil properties. The soil samples collected during profile studies and surface soil samples were analyzed for various physical and chemical properties and soil carbon parameters. From the data, carbon to nutrient ratio were calculated and results are presented in previous chapter. Further from the analyzed data the soil organic carbon maps are generated and presented. The soil site suitability of important crops of region was also judged and results are presented in chapter IV under appropriate heads.

The salient research findings emanating from the results presented, interpreted and discussed in previous chapter are briefly summarized below.

The twenty two (22) soil profiles spread over the Marathwada region were grouped as per agro-ecological zones. Out of 22 soil profiles, 13 soil profiles fall into agro-ecological zone 6.1 (Drought prone zone), 05 in Agro-ceological zone 6.2 (Assured rainfall zone), 01 in agro-ecological zone 6.3 (Moderate high rainfall zone) and 03 in agro-ecological zone 6.4 (Transitionally high rainfall zone). The Marathwada region found dominant in Vertisols followed by Inceptisols and Entisols.

All the pedons of Entisols are shallow in depth (0-30 cm). No significant difference was noted in soil colour except Kinwat pedon which is yellowish red in colour. Pedons are with disintegrated weathered murum, lime concentrations, clay loam texture, sub angular blocky structure. Soil consistency varied hard to slightly hard in dry condition, friable to very friable in moist condition and non sticky and plastic in wet condition.

The pedons classified under Inceptisols consists of moderately deep soils (0-70 cm), dark grayish brown to very darkish brown in colour, sub-angular blocky structure, expanding type of clay minerals that resulted in the development of cracks. Soil consistency varied from soft to hard in dry condition, friable in moist condition and slightly sticky and slightly plastic in wet condition.

The pedons classified under Vertisols were deep to very deep (100 cm to more than 120 cm), 2 to 3 cm wide cracks, slicken sides were well developed, sub-angular blocky to angular blocky peds. Soils were dark grey to dark yellowish brown, slightly hard to very hard and friable to moderately friable, very sticky and very plastic in wet conditions, powdery form of $CaCO_3$.

The saturated hydraulic conductivity of Entisols, Inceptisols and Vertisols varied from 1.0 to 7.0, 1.1 to 4.3 and 0.1 to 5.3 cm hr^{-1}, respectively. The clay content varied in the range of 43.3 to 58.7, 47.0 to 56.1, 50.1 to 62.1 per cent in Entisols, Inceptisols and Vertisols, respectively it was decrease with depth of profiles. The bulk density in Entisols, Inceptisols and Vertisols ranged from 1.27 to 1.57, 1.35 to 1.59 and 1.27 to 1.56 Mg m^3, respectively, which increased with depth of the soil profiles.

The pH value of Entisols, Inceptisols and Vertisols varied from 6.5 to 8.6, 7.8 to 8.3 and 7.8 to 8.7, respectively and categorized as alkaline in reaction. The EC of Entisols, Inceptisols and Vertisols ranged from 0.11 to 1.77, 0.22 to 2.00 and 0.20 to 1.35 dSm^{-1}, respectively and found safe for crop production.

The organic carbon content varied from 2.8 to 10.40, 2.3 to 9.75 and 0.19 to 1.04 g kg^{-1} in Entisols, Inceptisols and Vertisols, respectively. The organic carbon decreased with the increasing depth of the soil profiles. The $CaCO_3$ of Entisols, Inceptisols and Vertisols varied from 5.9 to 18.1, 3.80 to 14.50 and 2.8 to 18.9 per cent, respectively. The majority of soils were categorized as calcareous in nature. The cation exchange capacity of Entisols, Inceptisols and Vertisols ranged from 31.2 to 71.2, 33.3 to 63.5 and 38.2 to 78.2 (cmol $P^{(+)}$) kg^{-1}, respectively.

The available N, P and K in Entisols, Inceptisols and Vertisols of Marathwada region varied from 72.1 to 244.0, 1.80 to 12.60 and 136.7 to 460.7 kg ha^{-1} with an average value of 137.57, 4.43 and 293.02 kg ha^{-1}, respectively. Maximum soil samples categorized as low in nitrogen content low in phosphorus and high in potassium content. The available sulphur ranged from 2.36 to 11.67 mg kg^{-1}. Among the cations, calcium and magnesium in Entisols were varied in the range of 10 to 21.6 and 5.1 to 10.2 per cent, respectivley.

The available N, P and K values of Inceptisols ranged from 37.6 to 247.0, 1.5 to 11.8 and 224.9 to 583.6 kg ha^{-1} with a mean value of 143.6, 5.8 and 363.8 kg ha^{-1}, respectively. The available sulphur of soil profile varied from 1.06 to 27.96 mg kg^{-1}. The Ca and Mg varied from 10.0 to 18.6 and 5.5 to 8.7 per cent, respectively.

The available N, P and K of Vertisols varied in the range of 51.2 to 334.8, 1.0 to 27.10 and 229.6 to 618.2 kg ha^{-1} with an average value of 143.6, 7.93 and 430.1 kg ha^{-1}, respectively. The available sulphur ranged from 2.39 to 22.69 mg kg^{-1} in soil profiles of Vertisols. The calcium and magnesium varied in the range of 10 to 24.10 and 5.7 to 11.6 per cent, respectively.

The available Fe, Zn, Mn and Cu content in Entisols of Marathwada region were ranged from 2.40 to 5.21, 0.26 to 0.91, 5.14 to 18.23 and 0.97 to 3.63 mg kg^{-1} with an average value of 3.61, 0.49, 11.08 and 2.03 mg kg^{-1}, respectively.

The available Fe, Zn, Mn and Cu in Inceptisols of Marathwada region were varied between 2.20 to 4.79, 5.16 to 16.18, 0.21 to 1.06 and 1.57 to 4.23 mg kg^{-1} with a mean value of 3.63, 0.55, 10.1 and 2.44 mg kg^{-1}, respectively.

The available Fe, Zn, Mn and Cu content in Vertisols of Marathwada region found to be varied between 1.8 to 7.21, 0.41 to 1.39,2.36 to 21.89 and 0.59 to 4.51 mg kg^{-1}, respectively.

The soil organic carbon and inorganic carbon in Entisols were ranged from 0.33 to 1.42 and 0.93 to 2.17 per cent, respectively. The highest carbon content was observed in transitionally high rainfall zone than Drought prone and Assured rainfall zone. The total carbon was varied from 1.68 to 3.17 per cent and highest was in drought prone zone. The SMBC ranged between 10.1 to 629 g Mg^{-1} in Entisols of Marathwada region. The CO_2 evolution of Entisols varied in the range of 2.6 to 12.5 g 100^{-1} g 24 hr^{-1}. It was highest in Transitionally high rainfall zone than Drought prone and Assured rainfall zone. The C:N, C:P and C:S ratio in Entisols of Marathwada region ranged from 5.88 to 15.54, 10.75 to 24.74 and 6.78 to 15.02 with a mean value of 10.40, 18.33 and 10.41, respectively.

The soil organic carbon, inorganic carbon and total carbon in Inceptisols of Marathwada region varied in the range between 0.234 to 0.975, 0.456 to 1.74 and 0.826 to 2.295 per cent, respectively i.e. low to moderately high. The highest carbon content was observed in Transitionally high rainfall zone than Drought prone, Assured rainfall zone and Moderately high rainfall zone. The

SMBC was ranged between 109.7 to 744.34 mg g^{-1} in Inceptisols of Marathwada region. The CO_2 evolution of Inceptisols varied between 2.6 to 13.6 g 100^{-1} g hr^{-1}. The C:N, C:P and C:S ratios in Inceptisols of Marathwada region ranged from 4.10 to 16.75, 6.93 to 27.08 and 4.27 to 14.80 with an average value of 8.81, 16.17 and 9.36, respectively. The highest C:N, C:P and C:S ratio were found in Drought prone zone.

In Vertisols of Marathwada region, the soil organic carbon, inorganic carbon and total carbon ranged between 0.292 to 1.04, 0.360 to 2.28 and 0.789 to 2.689 per cent, respectively. The highest carbon content was observed in Drought prone zone as compared to Assured and Moderately rainfall zone. The SMBC of Vertisols of varied between 120.13 to 786.20 mg g^{-1}. The CO_2 evolution of Vertisols was ranged between 4.4 to 10.0 g 100^{-1} g hr^{-24}. The higher vlaue of SMBC was recorded in Assured rainfall zone. The 4.26 to 17.82, 9.26 to 26.00 and 3.80 to 15.24 with a mean of 10.90, 19.55 and 9.44, respectively.

Correlation coefficient values computed for various soil properties in relation to organic parameters showed that pH, EC and $CaCO_3$ were showed negative and significant correlation with various carbon parameters all soil orders under study.

The yield of the soybean ranged between (7.14 to 23.5 t ha^{-1}) in the study area. The highest yield was recorded in Pedon (P8, P7, P6). All pedons of Typic Haplusters are suitable (S2), Lithic Ustorthent (NS) and Typic Ustochrept (P12) were moderately suitable (S2) where as Typic Ustorthents were not suitable (NS) for soybean and pigeon pea. Typic Haplusterts found to be highly suitable (S1) for pegionpea followed by all Vertic Ustorthents pedons. The soils of Typic Haplusterts, Lithic Ustrothent and Vertic Ustochrept were moderately suitable (S2) for soybean. Further the Typic Haplusterts were moderately suitable to higher suitable for cotton crop cultivation.

From the result summarized above following conclusion can be drawn.

1. The soil of Marathawada region are very shallow to very deep, clayey, sub angular blocky, very dark gray brown to black. Taxonomically these are Lithic Ustrorthents, Typic Ustrothrents, Vertic Ustochrepts and Typic Haplusterts.

2. The soils are slight to moderately alkaline, safe in total soluble salt concentration and calcareous in nature. These parameters found to be increased with depth of soil.
3. The Entisols, Inceptisols and Vertisols showed variation in fertility status. In general the majority soil samples were categorized as low in N and P, high in Potassium and sufficient in Ca and Mg.
4. Irrespective of soil type the higher organic carbon content, SMBC and CO_2 was observed in transiently high rainfall zone than Drought prone and Assured rainfall zone. The total carbon was higher in Drought prone zone (due to high $CaCO_3$ content). The higher C:N, C:P and C:S ratio was found in Drought prone zone .
5. In Vertisols higher carbon content was observed in Drought prone zone. However, higher SMBC was recorded in Assured rainfall zone.
6. In Marathawada region organic carbon deficiency found to be spread over 46 to 67 % and showed less than 0.5 % organic carbon. The intensively cropped area (two to three crops in a year) had more spread of organic carbon deficiency than single cropped area.
7. The correlation coefficients values computed for various soil properties in relation to organic parameters showed that pH, EC and $CaCO_3$ had negative correlation with various soil carbon parameters.
8. The pedons of Lithic Ustorthents were not found suitable for soybean, pigeon pea and cotton. Typic Haplusterts found to be highly suitable for pigeon pea. Further Typic Ustorthents were not suitable for cotton cultivation. Vertic Ustochrept were moderately suitable for soybean and cotton and Typic Hapluserts were highly suitable for cotton.

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LITERATURE CITED

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APPENDIX

APPENDIX-I

PEDONS OF ENTIOLS

Pedon No. P1: Vaijapur (Non-irrigated)

Classification	:	Fine, Smectitsc , isohyperthermic, Lithic Ustorthents.
Location	:	Vaijapur, Aurangabad (Dist.) Latitude : $19^0$89”63 N, Longitude : $74^0$79”17 E,
Physiographic Position	:	Subdued Plateu.
Topography and slope	:	Very Gently Sloping 2-3% (50-150 cm)
Drainage	:	Moderately well drained
Vegetation	:	Neem, Babool,.
Land use	:	Onion, Cotton, Pigeon pea and Soybean
Parent material	:	Basaltic alluvium.
Remark	:	.

Plate No. 4.1. Show overall view of Pedon 1

Ap 0-15 cm	Very dark brown (10 YR 2/2), clay moderate medium sub angular blocky structure; slightly hard, friable, Slightly sticky and slightly plastic; may fine and many medium root’s, many, fine lime nodules; strong effervescence; strongly alkaline (pH 8.5); clear smooth boundary.
Bw_1 15- 27	Dark brown (10 YR 3/2) Clay; moderately medium sub angular blocky structure; friable, slightly sticky and lightly plastic; many fine roots many fine lime nodules; few fine pores; strong effervescence; strongly alkaline (pH 8.6) gradual smooth boundary.

Pendon No. P2 Kej: Beed (non-Irrigated)

Classification	:	Sandy clay, montmorilonitic, hyperthermic, Lithic Ustorthents .
Location	:	Kej (Tah.), Beed (Dist.), M.S. Lotitude 18^0 74" 22 N, Longitude 78^0 06 "48 E.
Physiographic Position	:	Plateau.
Topography and slope	:	Gently sloping 3-5 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Sandal.
Land use	:	Cotton, Soybean, Sugarcane, Mung, Udid.
Parent Material	:	Basaltic alluvium..
Remark's	:	Matrix effervescence there is Less $CaCO_3$ nodules. The lime is diffused and soft. No wild crack present.

Plate No. 4.2. Show overall view of Pedon 2

Ap	0-15 cm	Dark redish brown to dark brown (05YR 4/4) clay; moderate medium sub angular blocky structure; fine gravel, clay loam, very friable, non sticky and plastic, many fine roots, few fine pores, strong effervescence; moderatle alkaline (pH 8.3); clear smooth boundary.
Bw_1	15-27cm	Dark radish brown (05YR 4/4), clay; moderate medium sub angular blocky structure; friable, loose very friable, non-sticky and plastic; few fine roots; many very fine pores; strong effervescence; strongly alkaline (pH 8.5); abrupt wavy boundary.

Pedon No. P3 Kinwat : Nanded (non-irrigated)

Classification	:	Sandy clay, montmorilonitic, hyperthermic, Lithic Usorthents.
Location	:	Kinwat Forest. Lotitude 19^0 41" 36 N, Longitude $77^0$49 "19 E.
Physiographic Position	:	Hill valley.
Topography and slope	:	Gently sloping 8-10 % (50-150 m)
Drainage	:	Well drained.
Vegetation	:	Tig, Neem, Pimple, Apta.
Land use	:	Totally forest area.
Parent Material	:	Basaltic alluvium.
Remark's	:	No cracks observed. Less swelling in subsurface layer and slightly firm structure.

Plate No. 4.3. Show overall view of Pedon 3

Ap 0-15 cm	Yellowish red (5YR 4/4) dry, moist, gravelly loam, weak, fine moderate medium subangular blocky strtucture; slightly hard, triable, slightly sticky, and slightly plastic, abundance fine roots; common, modrate pores, medium basaltic gravells more than 25%, strong effervescences, rapid permeability, gradual smooth boundary, slighthry acdic (pH 6.8).
Bw_1 15-22 cm	Redish yellow (5YR 5/4) dry, moist, few fine roots, granual smooth boundary, weathered Basalt slightly acidic (pH 7.0).

Pedon No.: P4 Rohadi : Hingoli (Non-Irrigated)

Classification	:	Sandy clay, montmorilonitic, hyperthermic, Lithic Ustorthents.
Location	:	Rohadi, Hingoli (Tah.), Hingoli (Dist.), M.S.
	.	Lotitude $19^0 72$" 22 N, Longitude 78^0 82" 94 E.
Physiographic Position	:	Plateau.
Topography and slope	:	Gently sloping 3-5 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool.
Land use	:	Pigenpea, cotton, soybean.
Parent Material	:	Weather basaltic
Remark's	:	No cracks at the time of sampling.

Plate No. 4.4. Show overall view of Pedon 4

Ap 0-15 cm	Dark yellowish brown (10 YR3/2) clay; moderate medium sub angular blocky structure; slightly hard, friable, slightly sticky and slightly plastic, many fine roots; many fine, fine lime, alkaline (pH 7.3). gradual smooth boundary.
Bw_1 15-26 cm	Yellowish brown (10 YR 5/4) clay; moderate medium sub angular blocky structure; slightly hard with weathered basaltic material many fine to medium basaltic gravels; alkaline (pH 7.4).

Plate 4.1. Show overall view of Pedon P1

Plate 4.2. Show overall view of Pedon P2.

Plate 4.3. Show overall view of Pedon P3

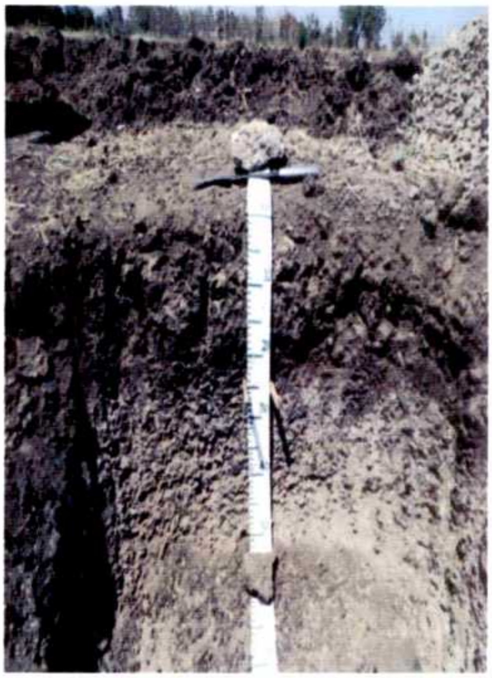


Plate 4.4. Show overall view of Pedon P4.

Pendon No. : P5 Ter: Osmanabad (Non-Irrigated)

Classification	:	Sandy clay, montmorilonitic, hyperthermic, Lithic Ustorthents.
Location	:	Ter, kalamb (Tah.), Osmanabad (Dist.), M.S. Lotitude $18^{0}18"36$ N, Longitude $76^{0}56"46$ E.
Physiographic Position	:	Subdueded plateau.
Topography and slope	:	Gently sloping 5-8 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango, Ber.
Land use	:	Maize, Mung, Soybean
Parent Material	:	Basaltic alluvium.
Remark's	:	Non cracks, Diffused lime through out.

Plate No. 4.5. Show overall view of Pedon 5

Ap 0-15 cm	Dark brown (10 YR 3/2) clay; moist; moderate medium sub angular blocky structure; slightly hard, friable, slightly sticky and slightly plastic, fine few roots few coarse and fine lime nodules; strong effervescence; strongly alkaline (pH 8.5)
Bw_1 15-20cm	Dark brown (10 YR 3/2) clay; moderate medium sub angular blocky stricter; friable, slightly sticky and slightly plastic, fine few roots with basaltic material many fine to medium basaltic gravel's, strong effervescence. Strongly alkaline (pH 8.5).

Pendon No: P6 Amhadpur : Latur (Non-Irrigated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Lithic Ustorents.
Location	:	Amhadpur , Latur (Dist.), M.S. Lotitude 18^{0}57"14 N, Longitude 77^{0}01"67 E.
Physiographic Position	:	Subdued plateau.
Topography and slope	:	Very Gently sloping 3-5 % (50-150 m)
Drainage	:	Well drained.
Vegetation	:	Neem, Babool.
Land use	:	Maize,Pigeon pea and Soybean.
Parent Material	:	Basaltic alluvium.
Remark's	:	Calcium carbonate are present in weathered basalt.

Plate No. 4.6. Show overall view of Pedon 6

Ap 0-15 cm	Dark yellowish brown (10 YR 4/3), moderate medium, angular structure; soft, very friable, non sticky and non plastic; many fine pores; many, very fine roots; slight effervescence; strongly alkaline (pH 8.3); clear smooth boundary.
Bw_1 15-26 cm	Dark yellowish brown (10YR 4/4) weak, fine granular structure; soft, very friable, non sticky and non plastic; few, fine pores, few, fine roots, slight effervescence; alkaline (pH 8.2) gradual smooth boundary.
	Above 28-35 cm, Weathered Basalt with mix calcium carbonate layer.

Pendon No.: P7 Lamantanda: Latur (Non-Irrigated)

Classification	:	Sandy clay loam, montmorilonitic, hyperthermic, Lithic Ustorthents .
Location	:	Laman tanda, Amhadpur (Tah.), Latur (Dist.), M.S.
		Lotitude $18^0 82"53$ N, Longitude $77^0 06"04$ E.
Physiographic Position	:	Subdued plateau.
Topography and slope	:	Very Gently sloping 1-3 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango.
Land use	:	Pigenpea, Soybean and wheat.
Parent Material	:	Basaltic alluvium.
Remark's	:	No cracks observed at time of sampling.

Plate No. 4.7. Show overall view of Pedon 7

Ap 0-15 cm Very dark grayish brown (10 YR 3/2); clay; moderate medium sub angular blocky structure; slightly hard, friable, sticky and plastic; few fine and many medium roots; many fine pores; nil to slight effervescence; neutral (pH 7.4): clear smooth boundary.

Bw_1 15-25 cm Very dark grayish brown (10 YR 3/2) clay; moderate medium sub angular block structure; friable sticky and plastic; fine common medium roots; many fine pores; nil to slight effervescence; neutral to alkaline (pH 7.5) gradual smooth boundary.

Pendon No: P8 Dhasadi: Parbhani (Non-Irrigated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Lithic Ustorents.
Location	:	Dhasadi, Parbhani (Tah.), Parbhani (Dist.), M.S.
		Lotitude $19^{0}07"18$ N, Longitude $76^{0}46"58$ E.
Physiographic Position	:	Subdued plateau.
Topography and slope	:	Very Gently sloping 1-3 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool.
Land use	:	Pigeon pea, Soybean.
Parent Material	:	Basaltic alluvium.
Remark's	:	No cracks.

Plate No. 4.8. Show overall view of Pedon 8

Ap 0-15 cm	Dark brown (10 YR 3/2), clay; moderate medium sub angular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; many fine and many medium roots; many fine pores many fine lime nodules; strong effervescence; strongly alkaline (pH 8.5); clear smooth boundary.
Bw_1 15-26 cm	Dark brown (10YR 3/2) clay; moderately medium sub angular blocky structure; friable, slightly sticky and lightly plastic; many fine roots many fine lime nodules; few fine pores; strong effervescence; strongly alkaline (pH 8.6) gradual smooth boundary.

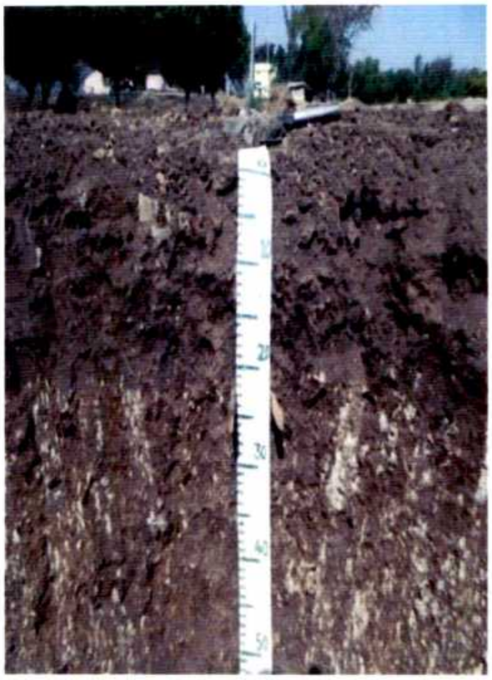


Plate 4.5. Show overall view of Pedon P5

Plate 4.6 Show overall view of Pedon P6

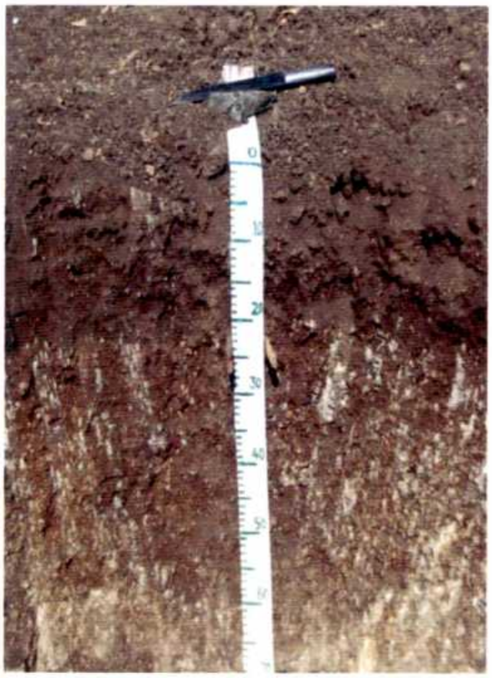


Plate 4.7. Show overall view of Pedon P7

Plate 4.8. Show overall view of Pedon P8

APPENDIX-II

PEDONS OF INCEPTISOLS

Pendon No. P9 : Aurangabad (Irrigated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Typic Ustochrepts.
Location	:	M.G.M. College of Agril. A.bad. Latitude : 19 89" 88 N, Longitude : 75 27" 69 E,
Physiographic position	:	Subdueded plateau.
Topography and slop	:	Gently sloping, 3-5% (50-150m)
Drainage	:	Moderately well drained
Vegetation	:	Mango, Neem, Babool, Ber.
Land use	:	Mango (Horticulture crop's) and Pigeonpea (Irregularly)
Parent Material	:	Basaltic alluvium.
Remark's	:	Firm and hard from 3-5 cm crack found on surface and it goes up to 2 ft. below.

Plate No. 4.9. Show overall view of Pedon 9

Ap- 0-13 cm	Dark brown to very dark grayish brown (10 YR 3/3), clay; moderate medium sub angular blocky structure friable, sticky and plastic: common very fine and fine roots; many fine lime nodules; many fine pores: strong effervescence; alkaline (pH 8.4) clear smooth boundary.
Bw_1 13-25 cm	Very dark grayish brown to dark brown (10 YR 3/2.5m), clay; moderate medium sub angular blocky structure; friable sticky and plastic; common fine roots; many fine, medium lime nodules; many fine pores; strong effervescence; strongly alkaline (pH 8.5) gradual smooth boundary.
Bw_2 25-65 cm	Dark brown (10 YR 3/3) clay, moderate medium angular blocky structure with pressure faces on ped surfaces; friable sticky and plastic; few fine roots; many fine medium lime nodules; strong effervescence: strongly alkaline (pH 8.7) gradual smooth boundary.

Pedon No. P10 Mandwa: Nanded (Non-Irrigated)

Classification	:	Clay lome, montmorilonitic, hyperthermic, Typic Ustochrepts.
Location	:	Mandwa, Kinwat (Tah.),Nanded (Dist.), M.S. Lotitude $19^0 54$" 88 N, Longitude $78^0 63$" 96'E.
Physiographic Position	:	Subdueded plateau.
Topography and slope	:	Gently sloping 3-5 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Teg, Neem, Babool.
Land use	:	Cotton, Jowar, Pigeon Pea, Soybean.
Parent Material	:	Basaltic alluvium.
Remark's	:	Calcium carbonate is present in granular from.

Plate No. 4.10. Show overall view of Pedon 10 and Plate 4.13 for $CaCO_3$ structure

Ap 0-15 cm	Dark Brown (10YR 2/3, 3/3), Clay; moist, moderate medium sub angular blocky structure; slightly hard, friable, slightly sticky and slightly plastic, many fine roots; many fine basaltic gravel 15-20 % many fine pores; slight effervescence; slightly acidic (pH 6.9); gradual smooth boundry.
Bw_1 15-45 cm	Very dark grayish brown (10YR 3/2), clay; clayloam, moderate medium subangular blocky structure; slightly hard, friable slightly sticky and slightly plastic, many fine roots; many fine; fine pores; moderate fine basaltic gravels 15-20% Nutral in (pH 7.1), gradual smooth boundary.
Bw_2 45-65 cm	Dark grayish brown (10YR 4/4) clay; moist; moderate medium sub angular blocky structure with developed slickensides; loose very friable, strcky and plastic; many fine lime nodules; many fine pores; slight effervescence; alkaline slight alkali (pH 7.2), gradual smooth boundry.

Pendon No. P11 Ausa: Latur (Non-Irrigated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Typic Ustochrepts.
Location	:	Ausa, Latur (Tah.), Latur (Dist.), M.S. Lotitude $18^{0}15"21$ N, Longitude $76^{0}30"53$ E.
Physiographic Position	:	plateau.
Topography and slope	:	Gently sloping 1-3 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango.
Land use	:	Mango, Soybean, Pigeon Pea, Sugarcane, Wheat.
Parent Material	:	Basaltic alluvium.
Remark's	:	2-3 cm crack found on surface.

Plate No. 4.11. Show overall view of Pedon 11

Ap 0-15 cm	Very dark grayish brown (10 YR 3/2); clay; moderate medium sub angular blocky structure; slightly hard, friable, sticky and plastic; few fine and many medium roots; coarse, fine lime nodules; many fine pores; slight effervescence; moderately alkaline (pH 8.2); clear smooth boundary.
Bw_1 15-30 cm	Very dark grayish brown (10 YR 3/2 M) clay; moderate medium sub angular block structure; friable sticky and plastic; few fine and many medium roots; coarse, fine lime nodules; many fine pores; slight effervescence; moderately alkaline (pH 8.3); gradual smooth boundary.
Bw_1 30-75 cm	Very dark grayish brown dark brown (10Yr 3/2 M) clay; moderate medium sub angular blocky structure with pressure faces on ped surface and weakly developed slickensides; friable, sticky and plastic; few fine roots; few fine medium lime nodules; many fine pores; slight effervescence; strongly alkaline (pH 8.5); gradual smooth boundary.

Pedon No. P12 Lohgaon : Parbhani (Non-irrigated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Typic Ustochrepts.
Location	:	Lohagon, Parbhani (Dist.), M.S. 13 km south from Parbhani. Lattiude 19^{0}10"41"N, Longitude 76^{0}47"35 E.
Physiographic Position	:	Plateau.
Topography and slope	:	Gently sloping 3-5 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango, Ber.
Land use	:	Cotton, Pigeon pea, soybean.
Parent Material	:	Basaltic alluvium.
Remark's	:	Very slight matrix effervescence at the surface. surface cracks of 3-5 cm wide during sampling and extend up to 20-25 cm and pressure force is present

Plate No. 4.14. Show pressure force

Ap 0-15 cm	Dark grayish brown to dark brown (10 YR 3/2.5,3) clay; moderate medium sub angular block structure; hard friable, sticky and plastic; common fine root and fine lime nodules; few fine pores; slight to strong effervescence; moderately alkaline (pH 8.2) ; clear smooth boundary.
Bw_1 15-45cm	Very dark grayish brown to dark brown (10 YR 3/2.5 M), clay; moderate medium sub angular blocky structure with pressure faces on ped surfaces; friable, sticky and plastic; few fine roots; many fine, medium and coarse lime nodules; slight effervescence; moderately alkaline (pH 8.3); gradual smooth boundary.
Bw_2 45-75 cm	Dark brown (10 YR 3/3 M), clay; moderate medium angular blocky structure with friable, sticky and plastic; fine few roots; fine, medium many lime nodules; slight effervescence; moderately alkaline (pH 8.0); abrupt smooth boundary.

Plate 4.9. Show overall view of Pedon P9

Plate 4.10 Show overall view of Pedon P10

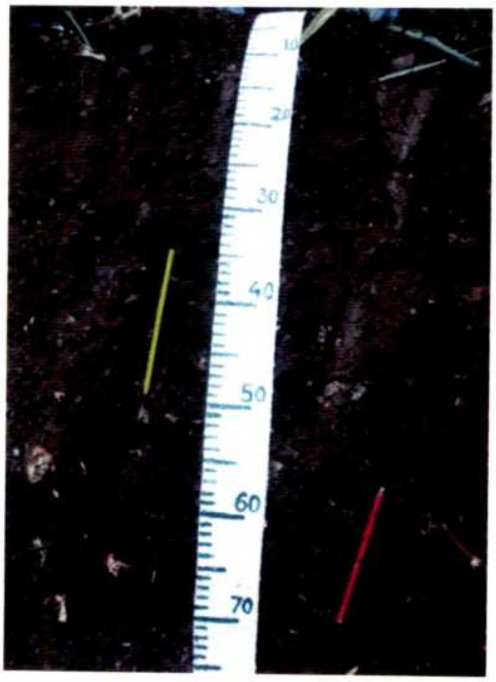


Plate 4.11. Show overall view of Pedon P11

Plate 4.12. Show overall view of Pedon P13

Pedon No. P13 Gevrai; Beed (Irrigated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Typic Haplusterts.
Location	:	Gevrai (Tah.), Beed (Dist.), M.S. Latitude $19^{0}22''03$ N, Longitude $76^{0}78''19$ E.
Physiographic Position	:	Plateau.
Topography and slope	:	Gently sloping 3-5 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango.
Land use	:	Cotton, Soybean and Pigeon Pea.
Parent Material	:	Basaltic alluvium.
Remark's	:	3-5 cm wide cracks upto 40 cm depth at the time of sampling. But cracks 8-10 cm wide in summer goes upto 45-50 cm depth. Lime nodule in the sub surface layers are very soft. Slight matrix effervescence less swelling in subsurface layer and slightly firm structure.

Plate No. 4.12. Show overall view of Pedon 13

Ap 0-15 cm	Very dark grayish brown (10 YR 3/2), clay; moderate medium sub angular blocky stricter; slightly hard; friable sticky and plastic; many fine roots; many very fine, finelime nodules; many fine pores; slight effervessence; strongly alkaline (pH 8.5); clear smooth boundary.
Bw_1 15-25cm	Very dark grayish brown to dark brown (10YR 3/2), Clay; moderate medium sub angular blocky structure; friable, sticky plastic; many fine roots; many very fine, fine lime nodules; many fine pores, slight effervescence; strongly alkaline (pH8.6); gradual smooth boundary.
Bw_2 25-60 cm	Very grayish brown (10 YR 3/2) clay; moderate medium sub angular blocky structure with pressure faces on ped surface; friable, sticky and plastic; common fine roots; many very fine, fine and medium fine lime nodules; many fine pores; slight to strong effervescence; strongly alkaline (pH 8.6); gradual smooth boundary.
Bs_1 60-90 cm	Brown (10 YR 4/3) clay, moderate medium to strong medium angular blocky structure with well developed slicken sides; friable firm, very sticky and very plastic; common fine, few medium lime nodules; strong effervescence strongly alkaline (pH 8.5). clear smooth boundary.

Plate 4.13. Show overall view of Granular form $CaCO_3$

Plate 4.14 : Pressure force P12

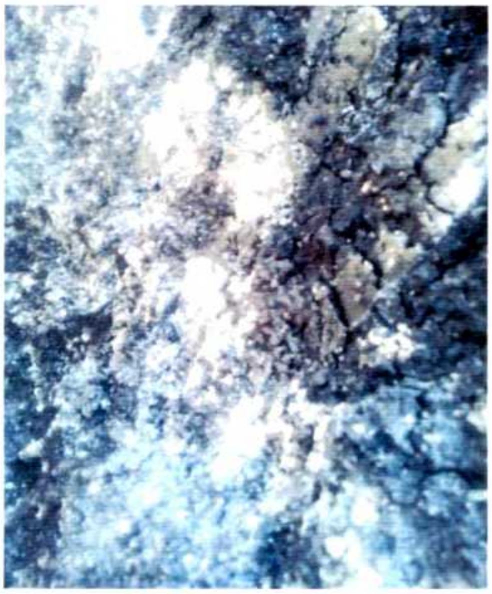


Plate 4.15. Show overall view of Powder form $CaCO_3$

APPENDIX-III

PEDONS OF VERTISOLS **Pedon No. P14 Beed (Irrigated)**

Classification	:	Clayey, montmorilonitic, hyperthermic, Typic Haplusterts.
Location	:	Beed (Tah.), Beed (Dist.), M.S. Latitude 18^{0}95"48 " N, Longitude 75^{0}75"80 E.
Physiographic Position	:	Plateau.
Topography and slope	:	Gently sloping 3-5 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Sandal.
Land use	:	Cotton, Soybean, Sugarcane, Pigeon Pea, Mung, Udid.
Parent Material	:	Basaltic alluvium.
Remark's	:	3.5 cm wide cracks up to 25-30 cm depth at the time of sampling. But cracks 5-8 cm wide in summer goes up to 45-50 cm depth. Lime nodules in the sub surface layers are very soft. Slight matrix effervescence. Less swelling in sub surface layer and slightly firm structure.

Plate No. 4.16. Show overall view of Pedon 14

Ap 0-15 cm	Very dark grayish brown to dark brown (10YR 3/2) clay; moderate medium sub angular blocky structure; slightly hard; friable, stickly and plastic; few fine roots; many very fine, fine lime nodules; many fine pores; strong effervescence; moderatle alkaline (pH 8.3); clear smooth boundary.
Bw_1 15-27 cm	Very dark grayish brown (10YR 3/2 M), clay; moderate medium sub angular blocky structure; friable, sticky and plastic; few fine roots; many very fine and few medium lime nodules; many fine pores; strong effervescence; strongly alkaline (pH 8.5); gradual smooth boundary.
Bw_2 27-60 cm	Very dark grayish brown (10YR 3/2 D), clay; moderate medium sub angular blocky structure with pressure face on ped surface; friable, sticky and plastic; few fine roots; few very fine and many fine lime nodules; many fine pores; strong effervescence; strongly alkaline (pH 8.6); gradual smooth boundary.
Bss_1 60-105 cm	Brown (10YR 4/3); clay; moderate medium angular blocky structure with well developed slicken sides; friable very sticky and very plastic; strong effervescence; strongly alkaline (pH 8.6): gradual smooth boundary.

Pedon No. P15 Hadgaon : Nanded (Irrigated)

Classification	:	Fine clayey, montmorilonitic, hyperthermic, Sodic Haplusterts.
Location	:	Hadgaon (Tah.), Nanded (Dist.) M.S. 55 km North Latitude $19^0$16'34" N, Longitude $76^0$45'38"E.
Physiographic Position	:	Plateau.
Topography and slope	:	Gently sloping 0-3 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango, Sandal.
Land use	:	Cotton, pigeon pea, Soybean, sugarcane, wheat.
Parent Material	:	Basaltic alluvium.
Remark's	:	Fine gravel and course gravel includes basalt, Quartz and $CaCo_3$.surface cracks of 3-5 cm wide upto 20-25 cm slight matrix effervescence.

Ap 0-15 cm	Very dark grayish brown to dark brown (10YR 3/2 M)clay; moderate medium sub angular blocky structure; slightly hard; very friable, sticky and plastic; many very fine and fine roots; many very fine lime nodules; many fine pores; strong effervescence; strongly alkaline (pH 8.5) clear smooth boundary.
Bw_1 15-40 cm	Very dark grayish brown to dark brown (10YR 3/2 M), clay; moderate medium sub angular blocky structure with pressure faces on ped surfaces; friable sticky plastic; common very fine and fine root's; many fine and few fine lime nodules; strong effervescence; strongly alkaline (pH 8.6) abrupt boundary.
Bw_2 40-65 cm	Very dark grayish brown to dark brown (10YR 3/2), clay moderate medium sub angular blocky structure; friable stickly and plastic; few very fine roots; many very fine, fine and few medium lime nodules; strong effervescence; strongly alkaline (pH 8.7).
Bws_1 65-105 cm	Very dark grayish brown (10YR 3/2) clay; moderate medium angular blocky structure will well developed slicken-sides; friable, firm sticky and plastic; few very fine roots; few very fine and fine lime nodules; strong effervescence; strongly alkaline (pH 8.6) clear smooth boundary.

Plate 4.16 Show overall view of Pedon P14

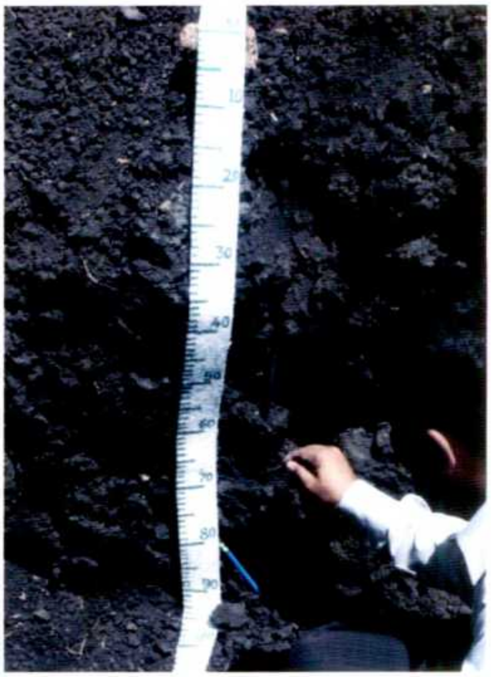


Plate 4.17 Show overall view of Pedon P21

Plate 4.18 Show overall view of Pedon P18

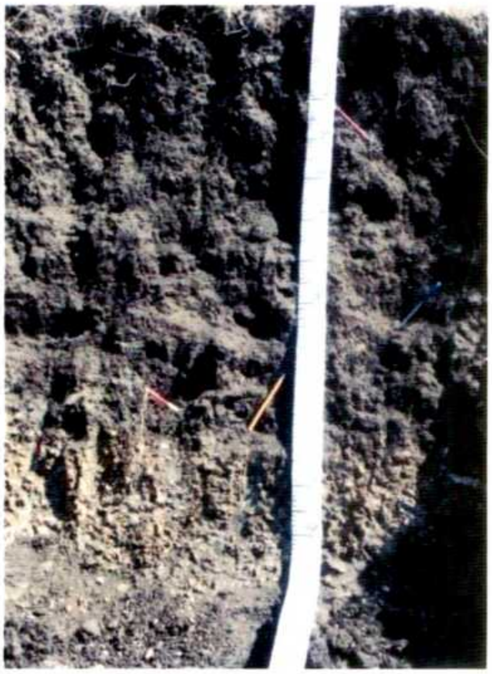


Plate 4.19 Show overall view of Pedon P19

Pedon No. P16 Bharaswada (Jalna) (Non-Irrigaated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Typic Haplusterts.
Location	:	Bharaswada,(Tah.), Jalna, M.S. Lotitude : 19 52" 28 N, Longitude : 75 69" 89 E,
Physiographic Position	:	Undulating landscape valley.
Topography and slope	:	Gently sloping 3-8 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango.
Land use	:	Cotton, Soybean, Maize, Pigeon pea, Jowar.
Parent Material	:	Basaltic alluvium.
Remark's	:	Cracks of 1-2 cm wide upto 40 cm. In the adjoining field 3-5 wide. Cracks all ready developed. Coarse quartz gravell in the profile throughout. Soft lime nodules which breaks with little pressure. Moderately alkaline (pH 8.2).

Plate No. 4.25. Show open craks on the surface near Pedons

Ap 0-15 cm	Very dark grayish brown (10 YR 3/2.5 D) clay; moderate medium sub angular blocky structure; slightly hard, very friable, sticky and plastic; very fine and many fine roots; many very fine lime concretions; many fine pores; strong effervescence; moderately alkaline (pH 8.2).
Bw_1 15-35cm	Very dark grayish brown to dark brown (10 YR 3/2.5 M), clay; moderate medium sub angular blocky structure; friable; sticky and plastic; many very fine and few fine root; many very fine and lime concretions; many fine pores; strong effervescence; moderately alkaline (pH 8.3)
Bw_2 35-65 cm	Very dark grayish brown (10YR 3/2), clay; moderate medium sub angular to angular blocky and weak angular blocky structure with pressure faces on ped surface; friable sticky and plastic; many very fine and few fine roots; many very fine and fine lime nodules; many fine pores; strong effervescence; strongly alkaline (pH 8.5).
Bss_1 65-110 cm	Vary dark grayish brown (10YR 3/2), clay; moderate medium angular blocky structure with well developed slicken sides; friable, sticky and plastic; common very fine roots; many very fine, fine and common medium lime nodules; strong effervescence; strongly alkaline (pH 8.7).
110 +	Stone and calcareous saprolit

Pedon No. P17 Govindpur : Osmanabad (Non-Irrigated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Typic Haplusterts.
Location	:	Goindpur, Kalamb (Tah.), Osmanabad (Dist.) M.S. about 13.5 km west in Beed road. Latitude $18^0$63"96 N, Longitude $76^0$78"70 E.
Physiographic Position	:	Subdueded plateau.
Topography and slope	:	Gently sloping 1-3 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango, Ber.
Land use	:	Sorghum, Pigeon pea, Soybean, sunflower, Gram and cotton.
Parent Material	:	Basaltic alluvium.
Remark's	:	Cracks of 1-2 cm wide up to 40 cm. In the adjoining field 3-5 wide. Cracks all ready developed. Soft lime nodules which breaks with little pressure.

Plate No. 4.23. Show overall view of Pedon 17

Plate No. 4.24. Show lime nodules with slickensides

Ap 0-15 cm	Very dark grayish brown (10 YR 3/2) clay; moderate medium sub angular blocky structure; slightly hard, friable, very sticky and very plastic many fine roots; many fine lime nodules; few fine pores; strong effervescence; strongly alkaline (pH 8.5); clear smooth boundary.
Bw_1 15-30cm	Very dark grayish brown to dark brown (10 YR 3/2.5 M), clay; moderate medium sub angular blocky structure; friable; sticky and plastic; many fine roots; many fine lime nodules; few fine pores; strong effervescence; strongly alkaline (pH 8.6) ; gradual smooth boundary.
Bw_2 30-60 cm	Very dark grayish brown (10YR 3/2), clay; moderate medium sub angular blocky structure with pressure faces on ped surface; friable; sticky and plastic; many fine roots; many fine lime nodules; few fine pores; strong effervescence; strongly alkaline (pH 8.8): gradual smooth boundary.
Bss_1 60-100 cm	Vary dark grayish brown (10YR 3/2), clay; moderate medium sub angular to angular blocky structure with well developed slickensides; friable, sticky and plastic; few fine roots; many fine lime nodules; strong effervescence; strongly alkaline (pH 9.1) gradual smooth boundary.

Pedon No. P18 Wadgaon : Osmanabad (Irrigated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Typic Haplusterts.
Location	:	Wadgaon, Osmanabad. Latitude 18^{0}28"68 N, Longitude 76^{0}09"97 E.
Physiographic Position	:	Plateau.
Topography and slope	:	Gently sloping 3-5 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango, Cotton, Ber.
Land use	:	Mango (*Margi indica*)
Parent Material	:	Basaltic alluvium.
Remark's	:	Weakly to well developed slickensides but due to moisture it disrupts during opening. Matrix effervescence through out and increasing with depth. At present cracking is very less 3-5 cm wide up to 10-15 cm depth But in summer the soil creaks 10-15 cm wide goes up to 45-50 cm depth.

Plate No. 4.25. Show overall view of cracks open on the surface near pedon

Plate No. 4.25. Show well developed slickensides and peds

Ap	0-15 cm	Very dark grayish brown (10 YR 3/2) clay; moderate medium sub angular blocky structure; friable sticky and plastic; many very fine and fine roots; few fine; few coarse and fine lime nodules; strong effervescence; moderately alkaline (pH 8.5).
Bw_1	15-33cm	Very dark grayish brown (10 YR 3/2 M), clay; moderate medium sub angular blocky structure; friable; sticky and plastic; many very fine roots; few fine lime nodules; strong effervescence; moderatly alkaline (pH 8.4).
Bw_2	33-65 cm	Very dark grayish brown (10YR 3/2), clay; moderate medium angular blocky structure with well developed slicken side; friable, sticky and plastic; few fine roots; few fine lime nodules strong effervescence; moderately alkaline (pH 8.3).
Bss_1	65-102 cm	Vary dark grayish brown (10YR 3/2), clay; moderate medium angular blocky structure with well developed slickensides; friable, sticky and plastic; few fine roots; few fine lime nodules; many fine pores; strong effervescence; strongly alkaline (pH 8.7)

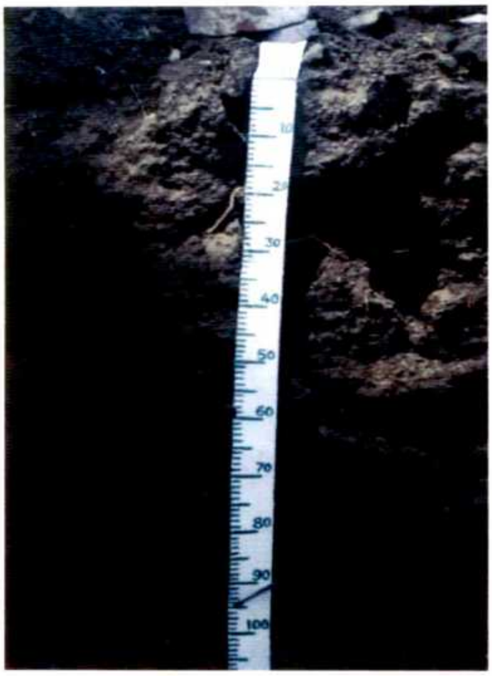


Plate 4.20 Show overall view of Pedon P20

Plate 4.21 Cracks depth of Pedon P20

Plate 4.22 Cracks depth of Pedon P18

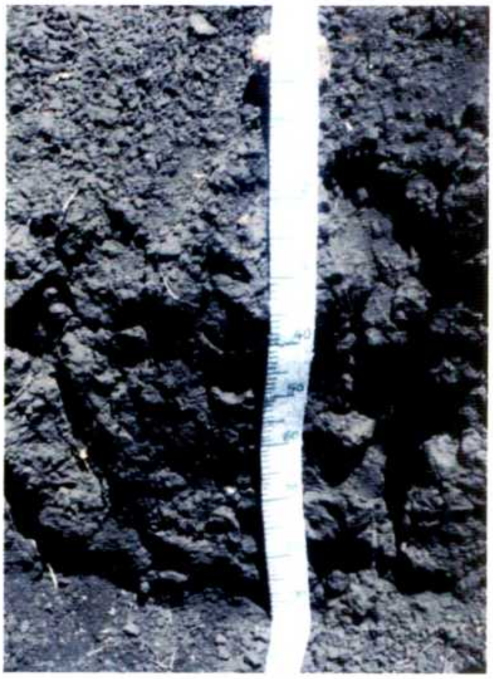


Plate 4.23 Cracks depth of Pedon P17

Pedon No. P19 Latur (Irrigated)

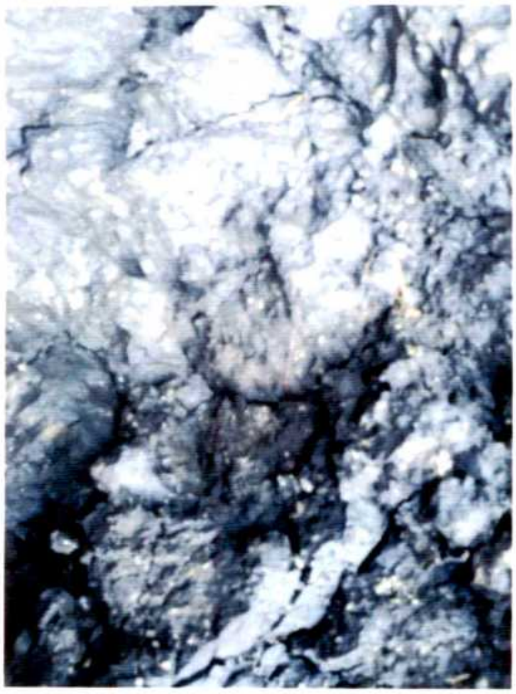
Classification	:	Clayey, montmorilonitic, isothermic, Typic Haplusterts.
Location	:	Agriculture college.of Latur, latitude 18 41"96 N, longitude 76 61" 84 E,
Physiographic Position	:	North Deccan Upper
Topography and slope	:	Very gently sloping 1-3 % (50-150 cm) moderate erosion, Normal.
Drainage	:	Moderately well drained
Vegetation	:	Neem, Babool, Mango.
Land use	:	Pigeon pea, Soybean, Wheat and cotton.
Parent material	:	Basaltic alluvium.
Remark	:	3-5 cm creak found on surface and it goes up to 2 ft. below.

Ap 0-25 cm	Very dark brown (10 YR 3/2), clay moderate medium sub angular blocky structure; slightly hard, friable sticky and plastic; few fine and many medium root's, coarse, fine lime nodules; many fine pores; slight effervescence; moderately alkaline (pH 8.1); clear smooth boundary.
Bw_1 25-60 cm	Dark brown (YR 10 3/3), clay, medium moderate sub angular blocky structure; friable, sticky and plastic, thick broken cutans, slightly hard, medium effervences; moderately alkaline (pH 8.4) clear smooth boundary.
Bw_2 60-90 cm	Dark brown (10 YR 3/3) clay loam, to clay moderate medium sub angular blocky with thick broken cutans, few fine roots, hard sticky and plastic, weakly developed slickensides; medium effervences, strongly alkaline (pH 8.4) diffuse smooth boundary.
Bsw_1 90-120 cm	Vary dark grayish brown (10YR 3/2) clay loam medium strong sub angular blocky structure, hard and well developed slicken sides; frible, sticky and plustic, many fine pores; slight effervences, strongly alkaline (pH 8.7) with clear smooth boundary. Mixed with weathed basalt.

Pedon No. P20 Babhulgaon : Latur (Irrigated)

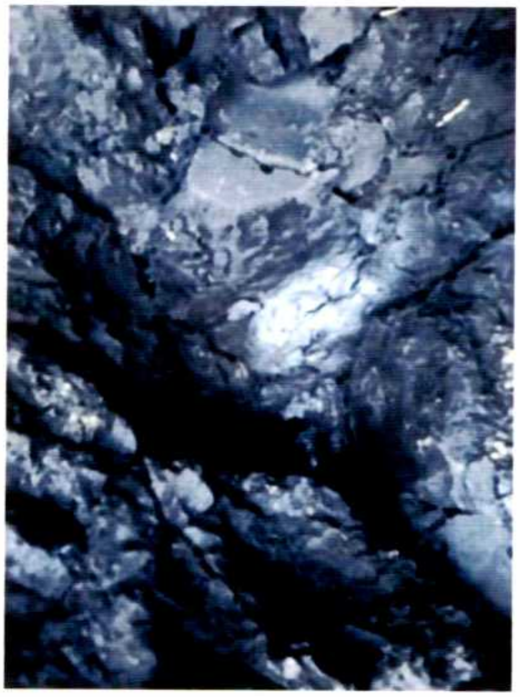
Classification	:	Fine clayey, montmorilonitic, hyperthermic, Typic Haplusterts.
Location	:	Babhulgaon, Latur (Dist.), M.S. 13 km. west of Latur-Babhulgaon, road. (Near by dairy) latitude 19°24"93 N, longitude 75° 61"37 E,
Physiographic Position	:	Subdued plateau
Topography and slope	:	Very gently sloping 1-3% (50-150 cm)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool.
Land use	:	Sugarcane, Cotton, Soybean, Pigeon pea intercropping, Sorghum
Parent Material	:	Basaltic alluvium.
Remark's	:	Granular $CaCo_3$ nodules are present at the time of sampling.

Ap 0-20 cm	Very dark grayish brown (10YR 3/2) clay; moderate medium sub angular blocky structure; slightly hard, friable, sticky and plastic; many fine and many medium roots; many fine pores; nil to slight effervescence; neutral (pH 7.2); clear smooth boundary.
Bw_1 20-45cm	Very dark grayish brown (10 YR 3/2) clay; moderate medium sub angular blocky structure with pressure faces on ped surfaces; friable, sticky and plastic; fine, common medium roots; many fine pores; nil to slight effervescence; neutral (pH 7.3); gradual smooth boundary.
Bw_2 45-90	Very dark grayish brown (10YR 3/2.5 M) clay; moist; moderate medium sub angular blocky structure with well developed slickensides; loose very friable, strcky and plastic; many fine lime nodules; many fine pores; slight effervescence; alkaline slight alkali (pH 7.3), gradual smooth boundry.
Bss_1 90-110 cm	Very dark grayish brown (10 YR 3/2), clay; moderate medium sub angular to angular blocky structure with, pressure faces on ped surface; well developed slickenside's; friable, sticky and plastic; common fine roots; few fine and medium lime nodules; many fine pores; nil to slight effervescence; neutral (pH 7.4) abrupt boundary



Pedon 14

Pedon 17



Pedon 18

Pedon 21

Plate 4.24. Photograph of well developed slickensides tilted to an angle of 50-60 Degree from horizontal breaking into angular blocky peds

Pedon No. P21 Chudawa : Nanded (Irrigated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Sodic Haplusterts.
Location	:	Chudawa (Tah.), Nanded (Dist.) M.S. 3 km North Latitude 19^{0}11'00" N, Longitude 77^{0}07'10"E.
Physiographic Position	:	Plateau.
Topography and slope	:	Gently sloping 1-3 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango, Sandal.
Land use	:	Cotton, pigeon pea, Soybean, sugarcane, wheat.
Parent Material	:	Basaltic alluvium.
Remark's	:	Cracks open 1-2 cm wide at the surface tapering to 70 cm depth

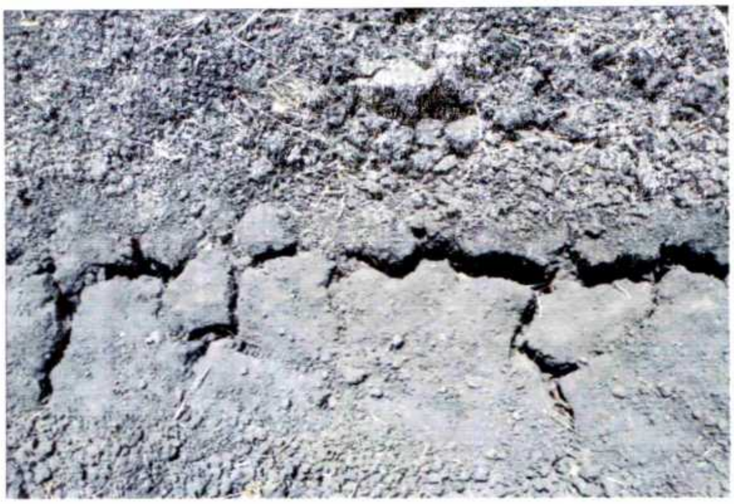
Plate No. 4.24. Show well developed slickensides and peds

Ap 0-15 cm	Very dark grayish brown to dark brown (10YR 3/2 M)clay; moderate medium sub angular blocky structure; slightly hard; very friable, sticky and plastic; many very fine and fine roots; many very fine lime nodules; many fine pores; strong effervescence; strongly alkaline (pH 8.5) clear smooth boundary.
Bw_1 15-40 cm	Very dark grayish brown to dark brown (10YR 3/2 M), clay; moderate medium sub angular blocky structure with pressure faces on ped surfaces; friable sticky plastic; common very fine and fine root's; many fine and few fine lime nodules; strong effervescence; strongly alkaline (pH 8.6) abrupt boundary.
Bw_2 40-65 cm	Very dark grayish brown to dark brown (10YR 3/2), clay moderate medium sub angular blocky structure; friable stickly and plastic; few very fine roots; many very fine, fine and few medium lime nodules; strong effervescence; strongly alkaline (pH 8.7).
Bws_1 65-95 cm	Very dark grayish brown (10YR 3/2) clay; moderate medium angular blocky structure will well developed slicken-sides; friable, firm sticky and plastic; few very fine roots; few very fine and fine lime nodules; strong effervescence; strongly alkaline (pH 8.6) clear smooth boundary.

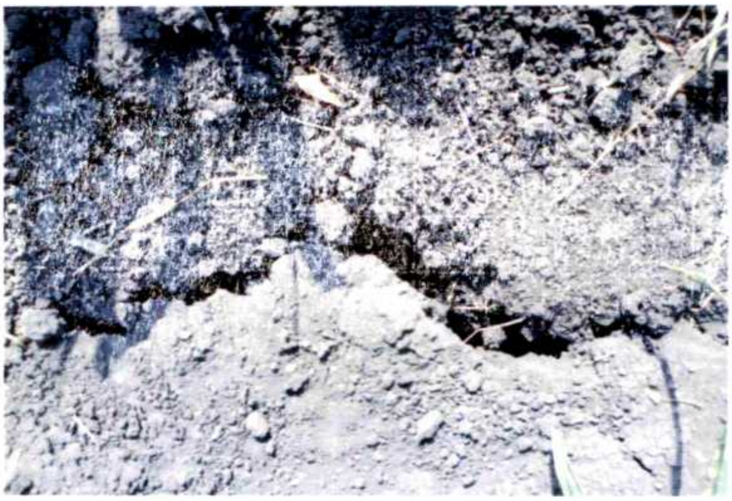
Pedon No. P22 Ranjni : Jalna (Irrigated)

Classification	:	Clayey, montmorilonitic, hyperthermic, Typic Haplusterts.
Location	:	Ranjni, Jalna (Dist.) M.S. Latitude $19^0 40^0$50N, Longitude 76^0 06''33E.
Physiographic Position	:	Subdueded plateau.
Topography and slope	:	Gently sloping 1-3 % (50-150 m)
Drainage	:	Moderately well drained.
Vegetation	:	Neem, Babool, Mango, Ber.
Land use	:	Sorghum, Pigeon pea, sunflower, Cotton, Gram...
Parent Material	:	Basaltic alluvium.
Remark's	:	Cracks open 1-2 cm wide at the surface and tapering to 40 cm depth

Ap 0-15 cm	Very dark grayish brown (10 YR 3/2) clay; moderate medium sub angular blocky structure; slightly hard, friable, very sticky and very plastic many fine roots; many fine lime nodules; few fine pores; strong effervescence; strongly alkaline (pH 8.5); clear smooth boundary.
Bw_1 15-30cm	Very dark grayish brown to dark brown (10 YR 3/2.5 M), clay; moderate medium sub angular blocky structure; friable; sticky and plastic; many fine roots; many fine lime nodules; few fine pores; strong effervescence; strongly alkaline (pH 8.6) ; gradual smooth boundary.
Bw_2 30-60 cm	Very dark grayish brown (10YR 3/2), clay; moderate medium sub angular blocky structure with pressure faces on ped surface; friable; sticky and plastic; many fine roots; many fine lime nodules; few fine pores; strong effervescence; strongly alkaline (pH 8.8): gradual smooth boundary.
Bss_1 60-90	Vary dark grayish brown (10YR 3/2), clay; moderate medium sub angular to angular blocky structure with well developed slickensides; friable, sticky and plastic; few fine roots; many fine lime nodules; strong effervescence; strongly alkaline (pH 9.1) gradual smooth boundary.



Pedon 14



Pedon 16

Pedon 18

Plate 4.25. Photograph of cracks open on the surface near Pedons

APPENDIX–IV

Total macronutrient of Entisol of Marathwada.

Sr. No	Agro Eco Logical Zone	Pedon	Horizon	Depth (cm)	Total macro nutrient (%)		
					N	P	S
1	6.1 Drought prone zone	Vaijapur P1	Ap	0-15	0.09	0.041	0.088
			A	15-28	0.086	0.063	0.096
		Kej P2	Ap	0-15	0.087	0.05	0.092
			A	15-27	0.092	0.047	0.091
		Ter P5	Ap	0-15	0.081	0.039	0.075
			Ac	15-20	0.073	0.037	0.071
		Amhadpur P6	Ap	0-15	0.072	0.042	0.069
			A	15-25	0.069	0.045	0.072
		L.Tanda P7	Ap	0-15	0.083	0.041	0.081
			Ac	15-30	0.075	0.043	0.08
2	6.2 Assured rainfall	Dhasadi P8	Ap	0-15	0.081	0.047	0.079
			Ap	15-26	0.077	0.051	0.076
		Kinwat P3	Ap	0-15	0.096	0.063	0.094
			C	15-20	0.087	0.059	0.09
3	6.4 Transistionally high rainfall	Rohadi P4	Ap	0-15	0.083	0.036	0.078
			A	15-26	0.075	0.041	0.065

Total macronutrient of Inceptisol of Marathwada

Sr.No.	Agro Eco Logical Zone	Pedon	Horizon	Depth (cm)	Total Macro Nutrient (%)		
					N	P	S
1	6.1 Drought prone zone	A'bad P9	Ap	0-13	0.085	0.051	0.087
			A	13-25	0.087	0.049	0.081
			Bw	25-45	0.076	0.045	0.073
		Ausa P11	Ap	0-15	0.076	0.047	0.086
			B	15-30	0.075	0.043	0.081
			Bw	30-75	0.065	0.035	0.07
		Gavrai P13	Ap	0-15	0.068	0.039	0.061
			B	15-25	0.071	0.041	0.056
			Bw	25-60	0.074	0.033	0.058
2	6.2 Assured Rainfall	Lohagaon P12	Ap	0-15	0.078	0.039	0.061
			B	15-45	0.061	0.031	0.058
			Bw	45-75	0.063	0.029	0.053
3	6.4 Transitionally high rainfall	Mandawa P10	Ap	0-15	0.093	0.057	0.092
			A	15-45	0.089	0.063	0.086
			Bw	45-60	0.076	0.04	0.071

Total macronutrient of Vertisol of Marathwada .

Sr.No.	Agro Eco Logical Zone	Pedon	Horizon	Depth (cm)	Total Macro Nutrient (%)		
					N	P	S
1	**6.1Drought prone zone**	Beed P14	Ap	0-15	0.092	0.052	0.09
			A	15-27	0.083	0.05	0.081
			Bw	27-60	0.071	0.047	0.086
			Bssk	60-100	0.053	0.019	0.071
		Govindpur P17	Ap	0-15	0.081	0.056	0.091
			A	15-30	0.078	0.049	0.083
			Bw	30-60	0.067	0.031	0.081
			Bssk	60-105	0.057	0.022	0.068
		Wadgaon P18	Ap	0-15	0.087	0.038	0.082
			A	15-33	0.061	0.037	0.079
			Bss1	33-65	0.06	0.038	0.076
			Bssk	65-100	0.069	0.039	0.088
		Latur P19	Ap	0-25	0.067	0.042	0.081
			Bw1	25-60	0.057	0.025	0.08
			Bw2	60-90	0.037	0.018	0.071
			Bssk	90-120	0.091	0.056	0.091
		Babulgaon P20	Ap	0-20	0.089	0.047	0.082
			Bw1	20-45	0.051	0.041	0.079
			Bw2	25-90	0.047	0.033	0.068
			Bssk	90-110	0.045	0.032	0.06
2	**6.2 Assured rainfall**	Bharaswada P16	Ap	0-15	0.071	0.051	0.072
			A	15-35	0.063	0.045	0.076
			Bw	35-65	0.065	0.042	0.068
			Bssk	65-102	0.061	0.02	0.051
		Chudawa P21	Ap	0-13	0.036	0.021	0.042
			B	13-32	0.025	0.016	0.031
			Bw	32-68	0.029	0.015	0.031
			Bss	68-100	0.076	0.039	0.085
		Ranjani P22	Ap	0-15	0.055	0.03	0.063
			Bw1	15-35	0.042	0.021	0.047
			Bw2	35-70	0.033	0.016	0.038
			Bssk	70-105	0.087	0.038	0.082
3	**6.3 Moderately high rainfall**	Hadgaon P15	Ap	0-15	0.087	0.041	0.088
			A	15-40	0.081	0.042	0.076
			Bw	40-65	0.072	0.032	0.072
			Bssk	65-105	0.059	0.02	0.068

Appendix-V

Soil site suitability criteria for Soybean on Marathwada.

Soil site characteristics	Degree of limitation					
	0 (None)	1 (1 Slight)	2 (Moderate)	3 (Severe)	4 (Very Severe)	
	S1		S2	S3	N1	N2
Climatic Characteristics						
Total rainfall (mm)	>850	750-850	650-750	550-650	<550	--
Rainfall growing season (mm)	>700	600-700	500-600	400-500	<400	--
Length of growing period (days)	>120	110-120	110-110	90-100	<90	--
Mean temp. growing season	25-28	--	28-30	30-34	>34	--
Mean minimum temp. growing season (^{0}C)	--	--	--	<20	--	--
Mean R.H. in growing season	>80	70-80	60-70	50-60	<50	--
Soil Site Characteristics						
Slope (%)	<3	<3	3-5	5-8	>8	--
Hydraulic conductivity (mm hr^{-1})	20-50	10-20	5-10	1-5, >50	<1	--
Drainage	Well	M.Well	Imperfect	Poor Excessive	V. Poor	--
Soil Characteristics						
Textrue	cl, sicl	l, sil, scl	sl, c	cm, ls	>25	--
Depth (cm)	<75	60-75	50-60	40-50	<40	--
$CaCO_3$ (%)	<5	5-10	10-20	>20	--	--
pH (1:2)	6.5-7.5	7.5-8.0	8.0-8.5	8.5-9.5	>9.5	--
EC (dsm^{-1})	<0.2	0.2-0.4	0.4-0.8	0.8-1.0	>10	--

Soil site suitability criteria for Pigeonpea on Marathwada.

Soil site characteristics	Degree of limitation					
	0 (None)	1 (1 Slight)	2 (Moderate)	3 (Severe)	4 (Very Severe)	
	S1		S2	S3	N1	N2
Climatic Characteristics						
Total rainfall (mm)	>1000	100-850	850-700	700-550	<550	--
Rainfall growing season (mm)	>850	850-750	750-600	600-500	<500	--
Length of growing period (days)	180-210	150-180	150-120	120-90	<90	--
Mean temp. growing season (^{0}C)	28-26	26-24	24-22	22-20	<20	--
Mean minimum temp. growing season (^{0}C)	35-32	32-28	28-26	26-24	<24	--
Mean R.H. in growing season	--	--	--	--	--	--
Soil Site Characteristics						--
Slope (%)	<2.0	2.0-3.0	3.0-5.0	5.0-8.0	>8.0	--
Hydraulic conductivity (mm hr^{-1})						--
Drainage	Well	Mod Well	Imperfect	Poor & Excessive	--	--
Soil Characteristics						--
Textrue	sicl, l, sil	c, sc,	v. fine	sandy	--	--
Depth (cm)	>125	125-100	100-50	50-25	<25	--
$CaCO_3$ (%)	>20	20-15	15-10	<10	<5	--
OC (%)	>0.75	0.75-0.5	0.5-0.2	<0.2	--	--
pH (1:2)	6.5-7.5	7.5-8.5	8.5-9.0	>9.0	--	--
EC (dsm^{-1})	<0.2	0.2-0.4	0.4-0.8	0.8-1.0	>1.0	--

Soil site suitability criteria for Cotton on Marathwada.

Soil site characteristics	Degree of limitation					
	0 (None)	1 (1 Slight)	2 (Moderate)	3 (Severe)	4 (Very Severe)	
	S1		S2	S3	N1	N2
Climatic Characteristics						
Total rainfall (mm)	850-1050	700-8502	550-700	<500	-	--
Rainfall growing season (mm)	750-950	600-750	450-600	<450	--	--
Length of growing period (days)	160-180	100-140	140-120	<120	--	--
Mean temp. growing season (^{0}C)	22-28	28-32	>32	<19	--	--
Mean minimum temp. growing season	--	--	--	<19	--	--
Mean R.H. in growing season	60-80	80-90	--	<50	--	--
Soil Site Characteristics						
Slope (%)	<1	1-3	3-5	>75	--	--
Hydraulic conductivity (mm hr^{-1})						
Drainage	Well	Mod Well	Imperfect	Poor, Excessive	--	--
Soil Characteristics						
Textrue	35-60	27-35	<27	--	--	--
Depth (cm)	>100	80-100	50-20	25-50	<25	--
$CaCO_3$ (%)	<5	5-10	10-20	>20	--	--
OC (%)	>1.00	0.75-1.0	0.5-0.75	<0.50	--	--
pH (1:2)	6.5-7.5	7.5-8.5	8.5-9.0	<6.5- >9.0	--	--
EC (dsm^{-1})	<1	1-2	2-4	4-8	--	--

Department of Soil Science and Agricultural Chemistry,

Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani

Title: Organic carbon mapping on Agro-Ecological Zones of Marathwada Region of Maharashtra State.

Name of Student: Malode K. R. Research guide: Dr. V. D. Patil

Reg. No. : 22P/ 2009A Year : 2013

ABSTRACT

The present investigation "Organic carbon mapping of Agro-ecological zones of Marathwada region of Maharashtra state" was carried out during 2009 to 2012 .A comprehensive study encompassing 22 soil profiles (Identified soils series) and 330 surface soil samples were evaluated for various soil properties. The soil samples collected during profile studies and surface soil samples were analyzed for various physical and chemical properties and soil carbon parameters. From the data, carbon to nutrient ratio was calculated and results are presented in previous chapter. Further from the analyzed data the soil organic carbon maps are generated and presented. The soil site suitability of important crops of region was also judged. It was aimed to study the organic carbon content in varied soil series and surface soils of agro ecological regions of Marathwada. To evaluate the physical and chemical properties and dynamics of nutrient status of soils of Marathwada region to find out relationship between C:N, C:P, and C:S ratio and soil properties under varied agro ecological regions of Marathwada.to prepare maps of soil organic carbon status and to study the cropping pattern and land use of agro ecological region of Marathwada.

The results showed that the soils of Marathawada region are very shallow to very deep, clayey, sub angular blocky, very dark gray brown to black. Taxonomically these are Lithic Ustrorthents, Typic Ustrothrents, Vertic Ustochrepts and Typic Haplusterts. The soils are slight to moderately alkaline, safe in total soluble salt concentration and calcareous in nature. These parameters found to be increased with depth of soil.The Entisols, Inceptisols and Vertisols showed variation in fertility status. In general the majority soil samples were categorized as low in N and P, high in Potassium and sufficient in Ca and Mg. Irrespective of soil type the higher organic carbon content, SMBC and CO_2 was observed in transiently high rainfall zone than Drought prone and assured rainfall zone. The total carbon was higher

in Drought prone zone (due to high $CaCO_3$ content). The higher C:N, C:P and C:S ratio was found in Drought prone zone .In Vertisols higher carbon content was observed in Drought prone zone. However, higher SMBC was recorded in Assured rainfall zone.In Marathawada region organic carbon deficiency found to be spread over 46 to 67 % and showed less than 0.5 % organic carbon. The intensively cropped area (two to three crops in a year) had more spread of organic carbon deficiency than single cropped area.The correlation coefficients values computed for various soil properties in relation to organic parameters showed that pH, EC and $CaCO_3$ had negative correlation with various soil carbon parameters.The pedons of Typic Ustorthents were not found suitable for soybean and pigeon pea. Typic Haplusterts found to be highly suitable for pigeon pea. Further Typic Ustorthents were not suitable for cotton cultivation. Vertic Ustochrept were moderately suitable for soybean and cotton and Typic Hapluserts were highly suitable for cotton.