

**EVALUATION OF SOIL QUALITY UNDER COTTON
GROWING SOILS OF PARBHANI DISTRICT**

BY

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B.Sc. (Agriculture)

A thesis submitted to

Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani

In partial fulfillment of the requirement for the degree of

**MASTER OF SCIENCE
IN
AGRICULTURE
(SOIL SCIENCE AND AGRICULTURAL CHEMISTRY)**



**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE, PARBHANI
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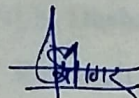
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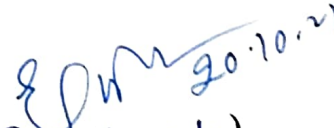



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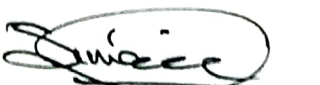

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ABBREVIATIONS AND SYMBOLS

/	Per
%	Per cent
ha.	Hectare
cm.	Centimeter
mm.	Millimeter
<i>et al.</i>	<i>Et alia</i> , and others
Fig.	Figure
sq. km	Square kilometer
i.e.,	that is
dSm-1	decimal per meter
g kg-1	Gram per kilogram
kg ha-1	Kilogram per hectare
mg kg-1	Milligram per kilogram
No.	number (s)
°C	degree Celsius
cmol (p ⁺) kg ⁻¹	Centimole per kilogram
Ppm	Parts per million
Mha	Million hectares
DTPA	Diethylene triamine Penta acetic acid
Temp.	temperature
viz.,	Vide licet, namely
J	journal
Soc.	society
Sci.	science
Dept.	department
Agri.	agriculture
Univ.	university
pH	Puissance de hydrogen

EC	Electrical conductivity
O.C	Organic carbon
CaCO ₃	Calcium carbonate
N	Nitrogen
P	Phosphorus
K	Potassium
Ca	Calcium
Mg	Magnesium
S	Sulphur
Fe	Iron
Mn	Manganese
Zn	Zinc
Cu	Copper
NBSS and LUP	National Bureau of Soil Survey and Land Use Planning
USDA	United State Department of Agriculture
WM	Weighted mean of soil control section
M	Meter
>	More than
MSL	Mean Sea Level
G.P. S	Global Positioning System
F.A. O	Food and Agriculture Organization
No.	number (s)
<	Less than
<i>Bt</i>	Bacillus Thuringensis
<i>Ssp.</i>	Species
PAWC	Plant Available Water Capacity
AWC	Available Water Capacity
CEC	Cation Exchange Capacity
NIV	Nutrient Index Value
LGP	Length of Growing Period

THESIS ABSTRACT

THESIS ABSTRACT

Title of the Thesis	:	“Evaluation of soil quality under cotton growing soils of Parbhani district”.
Name of the student	:	SuleSagarMalhari
Full Name of Research Guide	:	Deshmukh Mahesh Sharadrao
Department	:	Soil Science and Agricultural Chemistry
College/ University	:	VasatraoNaikMarathwadaKrishiVidyapeeth, Parbhani
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ABSTRACT

The present investigation entitled “Evaluation of soil quality under cotton growing soils of Parbhani district” was aimed for characterization, classification of soils of Parbhani district located in Maharashtra state between 18° 45” to 20° 10” N latitude and 76° 13” to 77° 39” E longitude. The geographical area of Parbhani is 6511 sq.km and climate of the studied area is hot, dry and sub humid with annual rainfall of 1089 mm. The mean maximum and minimum temperature were 33.06 °C and 26.03 °C respectively. Three (03) representative pedon from different physiographic unit was characterized and classified and forty-five (45) surface soil samples (0-30cm) from adjoining area of soil profile by G.P.S based survey samples were collected for laboratory analysis.

The cotton growing soils of Parbhani district were shallow to very deep, very dark gray (10 YR 3/1) to dark brown (10YR 3/4) in colour, granular to sub-angular blocky in structure and clay loam to clay in texture. The bulk density of soils varied from 1.40 to 1.79 Mg m⁻³. The plant available water capacity of soils varied from 53.06 to 258.85 mm and these soils were slightly to moderately alkaline in reaction (7.3 to 8.54). The electrical conductivity of soil was less than 1.0 dSm⁻¹. The organic carbon content in these soils were low to moderate and varied from 0.10 to 0.50 per cent. The calcium carbonate content varied from 5.09 to 28.4 per cent. The CEC of soils varied from 37.20 to 66.18 cmol (p⁺) kg⁻¹ and calcium is the dominant cation followed by magnesium, sodium and potassium in all profiles. The

base saturation per cent was varied from 94.94 to 98.53 per cent. The soils of the study area classified as Calcic Haplustepts and Calcic Haplusterts.

Correlation study showed that, the CEC was significant and positively correlated with clay ($r=0.98^*$) and there by increased with increasing clay content in soil. The depth of soil was positively correlated with PAWC ($r = 0.97^*$) and significantly positive correlated with clay ($r=0.98^*$). The PAWC increases with the increasing the depth of soil. The yield of cotton was positively correlated with PWAC ($r= 0.97^*$), Clay ($r = 0.99^{**}$) and depth ($r = 0.99^{**}$) of soil. This indicated that, the CEC, Clay content and depth of soil found to be responsible for yield reducing factors. Soil pH and CaCO_3 found to be negatively correlated with micronutrients indicating increasing CaCO_3 percent decreased the availability of nutrients. Soil fertility status varies from low to high. And the above results concluded that the soil clay content, CEC, and PAWC, pH and CaCO_3 are highly related with yield reducing factor for production of cotton in Parbhani district.

(Keywords: Cotton, Profile, Soil quality, Nutrient status, Correlation.)

CHAPTER – I
INTRODUCTION

CHAPTER - I

INTRODUCTION

Cotton is one of the world's leading agricultural crop, globally known as 'King of fiber' and play vital role in economy and produced in all over the world. It is a very important cash crop for small holding farmers and also one of the most exigent crops in terms of agrochemical inputs which are responsible for adverse effect on human health and environment. It is also an important fiber and cash crop grown widely in the tropical and subtropical regions around the world and most widely used natural fiber clothing today. Current estimates for world production are about 25 million tones annually, accounting for 2.5 Per cent of the world's arable land. India is the world's largest producer of cotton and cultivated on 12.61 million hectares. India is the only country to grow all the four species of cultivated cotton viz. *Gossypium arboreum ssp*, *Gossypium herbaceum ssp*, and *Gossypium barbadence ssp* and *Gossypium hirsutum ssp* besides hybrid cotton *Gossypium hirsutum ssp* represents 90 per cent of the hybrid cotton in India and all the current *Bt* cotton hybrids are *Gossypium hirsutum*.

Cotton is also known as "White Gold". Grown on black cotton soil which are a highly clayey soil. The black color in soils is due to the presence of titanium oxide in small concentration. The soil has a high percentage of clay, which is predominantly montmorillonite in structure and black or blackish grey in color. The clay mineral montmorillonite is mainly responsible for expansive characteristics of these soils. Cotton being deep rooted which absorpe large quantities of nutrients from the various soil layers. Nutrient management in cotton is very complex due to the simultaneous production of vegetative and reproductive structures during the active growth phase. Soil characterization in relation to evaluation of fertility status of soils of an area or region is an important aspect in context of sustainable agricultural production. Nitrogen, phosphorus, potassium, sulphur and zinc are important soil elements that control its fertility and yields of the crop. These soils are often difficult to cultivate, particularly for small farmers using hand held or animal drawn implements. Sub soil porosity and aeration are generally poor and roots of annual crop do not penetrate deeply. Farmers faced with these difficulties allow these soils to lie fallow for one or more rainy seasons (Pal *et al.* 2009). The most of the cotton

cultivated in India is 'eco-friendly' with little or no use of toxic chemicals in its production. Since people in advanced countries are very much health conscious, they demand for readymade cloths produced from certified organically grown cotton. But, maintaining soil fertility and soil productivity plays important role for sustainable production of organic cotton. It has very low bearing capacity and high swelling and shrinkage characteristics. Cotton is grown predominantly as a rainfed crop in Vertisols and Vertic integrates. These soils are characterized by dark gray to black in color, high clay content, particularly dominated by smectite mineral, neutral to alkaline in nature, high cation exchange capacity with exchangeable cations dominated by Ca^{2+} and Mg^{2+} and in some cases by Na^+ . Cotton under rainfed conditions normally suffers either due to lack of proper distribution of rains or heavy rains and terminal moisture stress. Cotton can be found as perennial tree like plants in tropical climate but is normally grown as shrub by annual in temperate climates it is a semi-xerophyte, grown in minimum temperature at 15°C is required for better germination. The optimum temperature for vegetative growth is 21°C to 27°C . Cotton is grown on a variety of soils ranging from well drained deep alluvial soils in the north to black clayey soils of varying depth in central region and in black and mixed black soils. Cotton is semi-tolerant to salinity and sensitive to water logging and thus prefers well drained soil.

Black cotton soils and associated black soils constitute a major soil group in India with the extent of 73.2 million hectares (Vertisols) mainly under rainfed agro eco-system (Zade, 2007). These soils had high stickiness and plasticity and showed slight to strong effervescence. The soils were showed well developed deep wide cracks in summer indicating high swell-shrink potential due to dominantly smectite clays in the arid climatic environments, the weathering of primary minerals contributes very little towards the formation of pedogenic carbonates as the prime chemical reaction that triggers the increase in pH, exchangeable magnesium and sodium on the exchangeable complex. The assessment of fertility status of soils that are being intensively cultivated with high yielding crops need to be carried out. It is important to monitor the fertility status of soil from time to time with a view to monitor the soil health. Soil available nutrients status of an area using Global Positioning System (GPS) will help in formulating site specific balanced fertilizer recommendation and to understand the status of soil fertility spatially and temporally (Mamaledesai *et*

al. 2012). From the view point of crop production, low organic matter is one of the major constraints in addition to low plant-available nutrients, particularly nitrogen (N), phosphorus (P), and zinc (Zn), thus affecting the productivity of these soils. In addition to poor fertility, limited soil moisture and poor drainage are the main soil-related problems in Vertisols. Swelling and shrinkage processes occur in all soils but Vertisols and their intergrades show a greater expression of this phenomenon. Though the cotton is an important cash crop of Maharashtra, the productivity is low because most of the area (96 - 97%) is under rainfed condition.

Maharashtra is the largest producer of cotton and produces 34 per cent of the total cotton production in India. Marathwada region of Maharashtra state occupies 64 lakh hectare area and geographically located between 17°52' North to 18°50' North and 76°18' East to 79°12' East. It has an average elevation of 631 meters (2,070 ft) above the mean sea level and comes under the Deccan Plateau region of Central India. Over 80 per cent production comes from the Khandesh, Vidarbha and Marathwada regions of the total area, 38 per cent occurring Maharashtra and 19.33 per cent of the total production and 21.33 % of the cotton area of the country, Gujarat is the second largest producer of the country.

The district of interest in Marathwada, the present investigation is in Parbhani district. The Parbhani district lies in Marathwada Division of Maharashtra state. The total geographical area of Parbhani district is 6511 (km)². Parbhani district lies between 18°45' to 20°10' North Latitudes and 76°13' to 77°39' East Longitude. The district is bounded on the north by Hingoli and Buldhana districts. On the east by Nanded and Hingoli and on the South by Latur and on West by Beed and Jalna districts. The area under cotton cultivation is 168.3 ha, with the production of 268.9 million tones and productivity of 4.18 q ha⁻¹.

Land evaluation is concerned with the assessment of land performance for specified land utilization purposes (Rossiter, 1996). Soil test values are most essential to obtain higher yields of high-quality cotton with greater fertilizer use efficiency. This would provide larger profits for farmers and stimulate local economics, such evaluation is essential in the process of land use planning because it may guide decisions on land utilization in such a way that the resources of the environment are optimally used and a sustained land management is achieved which

can guide the farmers in proper management of cotton cultivation, to reduce the cost of production as sustain and enhance cotton productivity which has specific climate and soil site requirements for optimum production, with the view the present study was undertaken on “**Evaluation of soil quality under cotton growing soils of the Parbhani district**” with following objectives.

Objectives:

1. To study the morphological, physical and chemical properties of cotton growing soils of Parbhani district.
2. To determine the macro and micro nutrients of cotton growing soils of Parbhani district.
3. To find out correlation between physico-chemical properties and available nutrients of cotton growing soils of Parbhani district.

CHAPTER – II
REVIEW OF LITERATURE

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REVIEW OF LITERATURE

A brief review of the literature related to the present investigation has been grouped under following heads

2.1 Morphological properties of soil

2.2 Physical properties of soil

2.3 Chemical properties of soil

2.4 Fertility status of soil

2.4.1 Available macronutrients

2.4.2 Available micronutrients

2.5 Correlation between physico-chemical properties and available nutrients of soil.

2.1 Morphological characteristics of soil.

Soils were developed from various types of parent material occurring on various land form unit widely distributed throughout the country and having wide difference in their morphological characteristics of soil. 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, 2006).

Vaidya and Pal (2002) studied the micropography or factor in the degradation of Vertisols in central India and reported that, the soil was very deep (7 /5) and very dark grayish brown to dark yellowish brown (10 YR 2.5/2 - 10 YR 4/4) surface horizon of all the pedons generally had a sub angular blocky structure and

hard to very hard (dry) and friable (moist) consistency interesting slickenside forming parallelepiped all soils effervesced with 10 per cent HCl.

Vaidya and Pal (2002) studied the soils of Pedhi watershed in Maharashtra and reported that soils were very deep (>150 cm) having very dark to dark yellowish-brown colours. The subsoil horizons had well developed intersecting slickensides with wedge-shaped structural peds that break into angular blocky structural peds. The cracks extended up to the slickenside zone in soils at micro low position while they cut through the slickenside's zones in soils of micro high position; in case of soil at micro high position, the effervescence with dilute HCl was strong to violent whereas in soils of micro low position it was slight

Reddy *et al.* (2004) studied on land evaluation for cotton suitability in a part of eastern Maharashtra and reported that, the soils on linear ridges rolling plain, pediment narrow valley's main valley floor are dark brown to very dark grayish brown in colour with 10 YR hue weak and sub angular blocky structure found in main and narrow valley.

Gabhane *et al.* (2006) studied the land evaluation for land use planning of a micro watershed in Vidarbha region of Maharashtra and stated that the soils were shallow to deep with color in the hue 10 YR, value ranged from 3 to 6 and chroma of 1 to 3. Soils were very dark grayish brown to dark brown in color the shallow soil pedons had sub angular blocky structure vertisol's showed well developed intersecting slicken sides.

Walke *et al.* (2012) studied GIS based multi criterion overlay analysis in soil suitability evaluation for cotton a case study in the soil of central India and found that the colour of soils were dark brown to very dark grayish brown (10 YR hues). Texture of soil varied from clay loam to clay and medium strong to medium moderate sub angular blocky structure found on surface and angular blocky structure found in subsurface horizon.

Malode (2013) studied the soils of Marathwada region of Maharashtra and reported that the soils were shallow to very deep in depth, dark greyish brown to dark yellowish brown in colour. The soil consistency varied from soft to very hard in

dry condition and friable in moist condition and non-sticky, non- plastic to very sticky, very plastic in wet condition.

Patil *et al.* (2013) characterized, classified and evaluated the soils and irrigation water in Osmanabad tehsil of Maharashtra and reported that the soils of Osmanabad tehsil were yellowish brown (10YR 5/6) to black (10YR2.5/1) in colour, calcareous in nature (0.7 to 19.37 %), very shallow to very deep in depth, sandy clay loam to clay in texture. The soils were granular to sub angular blocky in structure and non sticky, non plastic to very sticky very plastic in consistency.

Malode and Patil (2014) studied the soils of Marathwada and concluded that the soils were very dark grey to dark yellowish brown (10YR 3/1.5 to 10YR 4/4), very sticky and very plastic in wet condition of consistency.

Pawar *et al.* (2014) characterized and classified pomegranate growing soils of Osmanabad district of Maharashtra and revealed that the soils of the area were shallow to very deep in depth, soil colour varies from dark brown (10 YR 4/3) to dark yellowish brown (10 YR 4/4) in Lithic Ustorthents, very dark grey (10 YR 3/1) to dark brown (10 YR 3/3) in Typic Ustochrepts and black (10 YR 2.5/1) to very dark greyish brown (10 YR 3/2) in Typic Haplusterts. The soils of the area were sandyloam to clayey in texture and granular to angular blocky in structure. The sub-surface horizon showed angular blocky structure due to swell-shrink phenomenon of smectitic clay minerals.

Sekhar *et al.* (2014) studied on genesis characterization and classification of soils of eastern part of prakasm district of Andra Pradesh and noticed that the soils were shallow to very deep with imperfectly to well drain. The colour of soils varied from very dark grayish brown to dark yellowish brown horizon boundaries were clear to gradual in distinctness consistency of soil varied from soft to very hard loose to firm at moist condition and non sticky and non plastic to very sticky and very plastic (wet).

Bhaskar *et al.* (2015) studied the landscape planning for agro development at regional scale of cotton growing in Yawatmal district and reported that, soils were dark grey to brown matrix with 10 YR hue and clay texture

throughout profiles inherited from basalt distinct landsides within the calcium carbonate enriched in “B” horizon.

Malavath and Mani (2015) studied the genesis classification and evaluation of cotton growing soils and reported that the soil colour varied from very dark grey to dark grayish brown under dry and moist condition respectively. The soils were very deep and angular blocky in structure.

Sayambar (2015) studied on Tungi watershed in Latur district of Maharashtra and indicated that the soils were shallow to very deep, black to light brownish gray in colour granular to sub-angular blocky in structure non sticky, non-plastic to very sticky, very plastic in consistency.

Adkine (2016) studied on the soils of Krishna valley of Marathwada region, Maharashtra and reported that the soils were very shallow to very deep in depth, black (10 YR 2.5/1) to very pale brown (10YR 7/4) in colour.

Madu et al. (2017) studied the soil Pedon's of Jamuna par vision of Allahabad district of Uttar Pradesh and reported that the soils were moderately to deep soil and colors varied from 2.5 YR 4/4 (olive brown) to 10 YR 4/4 (dark yellowish brown) in moist condition, subsurface horizons of most of the Pedon's have falling under weak to moderate, fine to medium and most of Pedon's were sub angular blocky.

Aundhakar *et al.* (2018) studied the cotton growing soils of Beed district and reported that the depth of soil ranged from very shallow (18 cm) to deep. The soils were black to light yellowish brown (10 YR 2.5/1 to 10 YR 6/4) in water sub angular blocky to angular blocky in structure.

Chadar *et al.* (2018) studied the characterization, classification and soil site suitability evaluation of soils of college of agriculture, Latur and reported that soils were shallow to moderately deep, very dark grey (10 YR 3/1) to dark brown (10 YR 3/3) in colour granular to sub angular blocky in structure and salty clay loam to clay in texture.

Ghode *et al.* (2018) studied on characterization classification and evaluation of cotton growing soils of Nanded district and reported that the soils are

shallow to deep black (10 YR 2.5/1) to very pale yellow (10 YR 7/4) in color and granular to angular blocky structure loamy to clay in texture (13.4 to 70.77 %).

Prasad *et al.* (2018) studied physical properties of soils of some selected pedons at undulated hilly terrain of three villages named "Motidabdar, Chikhaldia and Daguniya" in Waghai taluka of Dangs district in South Gujarat. The bulk density of pedons of Motidabdar, Chikhaldia and Daguniya village found to mean value of 1.53, 1.60 and 1.57 Mg m⁻³ respectively. The mean percent of soil porosity (> 2mm) in Motidabdar village of pedon 1, 2 and 3 was 37.54%, 27.86% and 26.18% respectively, while mean value of the Chikhaldia village was lower and the Daguniya village higher as compared to Motidabdar village. In case of P2 and P3 mean percent of soil porosity of Chikhaldia and Daguniya village were higher than Motidabdar village. Coarse fragments of three villages contained >35% of gravels/coarse fragments (>2 mm), except upper few horizons of some pedon

Satish *et al.* (2018) studied the characterization and classification of the soils of Brahmanakotpur water shed in Andhra Pradesh and stated that the soils were poorly to well drained, very dark grey to strong brown colour with a hue of 10 YR, value ranged from 3 to 5 and chroma varied between 1 to 6.

Nawkhare (2020) assessed soil quality of Babhalgaon Village of Latur district for soil health and land resource management by using remote sensing and GIS techniques and observed morphological properties of soil indicated that soil depth of study area corresponds to shallow to moderately deep. The soil colours of study area are most soils of the study area were black to dark brown in colour. The soils have structure varied from, medium, moderate, sub angular blocky and medium, mmm moderate, angular blocky structure in Typic Haplusterts showed well-developed intersecting slickenside and wedge-shaped structural aggregates. This may be because of swell shrink properties of Vertisols. Consistency shows that in Typic Haplusterts varied from loose, friable, non sticky, non plastic to hard, firm, very sticky, very plastic in wet condition. While the soils consistency of Typic Haplusterts varied from slightly hard, extremely hard, firm very sticky, very plastic in wet condition and soil consistency of Typic Ustorthents varied from slightly friable, non-plastic, very sticky to very plastic in wet condition.

Purandhar and Naidu (2020) studied on characterization classification and fertility status of soils of Puttar Mandal in Chittoor district of Andhra Pradesh and reported that the soil color varied from light grey to very dark grey for few pedons with hue of 10 YR. The consistence of soil varied from soft to very hard (dry), loose to firm (moist) and non-sticky and non-plastic to very sticky and very plastic (wet).

Thale *et al.* (2020) studied characterization classification and soil site suitability of porograte growing soils of Latur district and found that the soils were very shallow to very deep reddish brown to dark grayish brown (5 YR 4/4 to 10 YR 4/2) clay to sandy loam in texture and granular to angular blocky in structure.

Wahane *et al.* (2020) studied the morphological properties of micro shed soil properties and land forms in relation to cotton based cropping system and observed that the soil colour ranged from very dark gray (2.5 YR) to very dark grayish brown (10 YR).

2.2 Physical properties of soil

Ali and Biswas (1971) studied retention and release behaviour of soil water as interrelated to mineralogy of the soil clays and revealed that the black soils, having montmorillonite as the dominant clay mineral which retained and released the largest amount of water followed by the alluvial (illitic) and lateritic (kaolinitic) soils and also reported that the nature and amount of the clays are significant factors in determining the water retention character of soils.

Vaidya and Pal (2002) studied the micro topography as a factor in the degradation of Vertisols in Central India and observed that the soils contain 51 to 86 per cent clay and 27 to 66 percent. The hydraulic conductivity of soils ranged from 5.9 to 29.8 mm hr⁻¹. The significant positive correlation between hydraulic conductivity and exchangeable cations Ca / Mg ($r = 0.52$) at 1 per cent.

Maji *et al.* (2005) studied the characterization and classification of land forms and soils over basaltic terrain in sub humid tropics of Central India and stated that the bulk density of the soils varies from 1.33 to 1.79 mg m⁻³. The available water holding capacity values in the study area vary from 97.9 to 199.5 mm.

Gabhane *et al.* (2006) studied the land evaluation for land use planning of a micro watershed in Vidarbha region of Maharashtra and found that the soils were clay in texture with clay content ranging from 34.4 to 74.4 per cent. The silt content ranges from 12.8 to 40 per cent and sand content of soil was less than 11 per cent.

Zade (2007) studied some deep shrink-swell soils of Marathwada region of Maharashtra to develop arable land use plan and stated that the soils were deep to very deep (100 to more than 150 cm). The cracks were 2 to 10 cm wide at the surface and extended up to a depth of 20 to 60 cm. The pressure faces were observed in all the profiles. Slickensides were well developed and peds broke into small subangular blocky to angular blocky peds. The soils were very dark gray to dark yellowish brown in color (10 YR 3/1.5 to 10 YR 4/4). The surface horizons of all the pedons had subangular blocky structure and slightly hard to hard (dry) and friable to moderately friable (moist) consistency.

Bhaskar *et al.* (2011) studied on land resource evaluation for optimal land use plant in cotton growing in Yawatmal district and stated that the clay content was less than 35 per cent and silt content is more than 40 per cent. The bulk density of these soils was ranged 1.57 to 1.79 mg m⁻³. These soils had plant available water up to 12.65 per cent.

Patil *et al.* (2013) characterized, classified and evaluated the soils and irrigation water in Osmanabad tahsil of Maharashtra and reported that soil situated in elevated area are sandy loam to silt loam in texture and high number of coarse fragments varied from 6.9 to 96 per cent. The soils developed on sloping land are sandy loam to clayey in texture whereas pedons located on low lying area are clayey in texture. Bulk density of soil above murrum layer ranged from 1.23 to 1.69 Mg m⁻³ and murrum layer ranged from 2.02 to 2.15 Mg m⁻³. The available water content of the soil ranged from 7.5 to 20.8 per cent. The saturated hydraulic conductivity of soil varied from 0.27 to 29.50 cm hr⁻¹.

Nagaraju and Gajbhiye (2014) studied on characterization and evaluation of soils of Kukadi command in Ahmednagar district of Maharashtra and found that the sand, silt and clay varied from (15.8 to 57.3) (14.0 to 25.1) (28.7 to 64.5 per cent) respectively in the soils of study area.

Pable *et al.* (2014) studied the soil quality assessment of rainfed cotton growing agro ecological sub regions of Vidharbha and reported that the pedons had fairly high clay content ranged from 39.81 to 67.64 per cent. The saturated hydraulic conductivity to be low and ranged from 1.54 to 3.20 cm hr⁻¹.

Sekhar *et al.* (2014) studied on genesis characterization and classification of soils of central and eastern part of Prakasm district of Andhra Pradesh and reported the clay content in the soils were varied from 2.03 to 57.24 per cent. The bulk density of different pedons varied from 1.27 to 1.93 mg m⁻³ water holding capacity of different pedons varied from 18.48 to 56.86 per cent.

Shinde (2015) studied on the soils of Oilseed Research Station, Latur, and concluded that, soils were clay to silty clay in texture. Bulk density ranged from 1.3 to 1.48 Mg m⁻³ and saturated hydraulic conductivity varied from 1.4 to 20.2 cm hr⁻¹

Vaidya and Dhawan (2015) Investigated land hybridization with tank silt impact on soil quality and productivity of soybean and reported that, the bulk density of these hybridized soil was varied from 1.31 to 1.78 mg m⁻³ and available water content in surface layer of hybridized soil for 1/3 bar varied from 31.4 to 46.4 percent and 15 bars varied from 16.6 to 31.1%.

Aundhakar *et al.* (2018) studied the characterization and classification in cotton growing soils of Beed district and reported that, the bulk density of these soils was varied from 1.24 to 1.97 mg m⁻³. The plant available water capacity varied from 82.25 to 3001.71 mm and saturated hydraulic conductivity varied from 1.30 to 22.7 cm hr⁻¹.

Chadar *et al.* (2018) studied the characterization classification and soil site suitability evaluation of soils of College of Agriculture Latur and observed that, the bulk density of soil varied from 1.24 to 1.79 mg m⁻¹. The saturated hydraulic conductivity of soil varied from 1.20 to 25.80 cm hr⁻¹ and coarse fragment of soil varied from 1.12 to 68.34 per cent. The plant available water capacity of soil varied from 58.29 to 228 mm.

Ghode *et al.* (2018) studied on characterization classification and evaluation of cotton growing soils of Nanded district and reported that the soil content high number of coarse fragments varies from 0.11 to 11.49 per cent. Bulk density of soil ranged from 1.29 to 1.88 mg m⁻³. Available water content of soil ranged from 7.3 to 29.1%. The saturated hydraulic conductivity of soil varies from 1.30 to 23.10 cm ha⁻¹.

Satish *et al.* (2018) studied the characterization and classification of the soils of Brahmanakor water shed in Andhra Pradesh and reported that particle size analysis revealed the clay content varied from 18.1 to 57.4 per cent. The silt fraction ranged from 5.6 to 52.2 per cent and sand content ranged from 8.4 to 70.1 per cent. The bulk density of different pedons varies from 1.17 to 1.62 mg m⁻³ and water holding capacity of different pedons ranged from 20.1 to 67.2 per cent.

Patil *et al.* (2019) studied on physico chemical properties in soils from Washi tehsil of Osmanabad district and reported that the average bulk density was 1.53 mg m⁻³ and average particle density 2.39 mg m⁻³ and porosity of soil was 35.95 percent.

Nawkhare (2020) assessed the soil quality of Bhabhalgaon village in 21 Latur district for soil health and land resource management by using remote sensing and GIS techniques and found that coarse fragment in soils was varied from 6.18 to 21.38 per cent. The bulk density of soils varied from 1.42 to 1.79 Mg m⁻³. The saturated hydraulic conductivity varied from 2.40 to 29.25 cm hr⁻¹. This variation attributed to textural difference. The plant available water capacity of the soils varied from 76.09 to 480.40 mm found to increase with depth of soil.

Thale *et al.* (2020) studied characterization classification and soil site sustainability of pomegranate growing soils of Latur district and stated that the bulk density of soils was ranged from 1.55 to 1.88 mg m⁻³. The plant available water capacity varied from 68.34 to 380.52 mm hr⁻¹. The saturated hydraulic conductivity of soils varied from 3.27 to 23.71 the PAWC content of soil varied from 68.34 to 93.33 mm hr⁻¹.

Wahane *et al.* (2020) studied the evaluation of cotton-based cropping system in relation to land forms and soil properties in a micro water shed and found that the surface soils showed moderate medium sub angular blocky structure, while the sub surface horizons had developed strong coarse angular blocky structure due high clay content sand content ranges between 3 to 55% the clay content varies from 56 to 78 percent the bulk density of air-dry clod ranges from 1.7 to 1.89 mg m⁻³.

2.3 Chemical properties of soil

Pal and Deshpande (1987) studied some Benchmark Vertisols of Central and western India to know the genesis and characteristics of clay minerals and observed that montmorillonite of the montmorillonite-nontronite series is nearer to the fine clay smectite and concluded that the di octahedral smectite is the first weathering product of plagioclase-rich Deccan basalt. The Deccan basalt rock rich in plagioclase can readily give rise to di-octahedral smectite as the first weathering product over an aridic to humid climate.

Vaidya and Pal (2002) studied the micro topography as a factor in the degradation of Vertisols in Central India and reported that soils contain 51-86 per cent clay and 27-66 per cent fine clay (0.2). All soils were calcareous (75%). The soils were moderately alkaline (pH > 8.3) where as those of pH was moderately to strongly alkaline (8.1 to 8.9). The organic carbon content varies from 0.2 to 0.9 per cent and electrical conductivity of saturation extract is much less than 4 dsm⁻¹ except in soils of 9 and 11 pedons.

Maji *et al.* (2005) studied the characterization and classification of land forms and soils over basaltic Terrain in Sub humid tropics of Central India and stated that, the pH value of soil ranges from 6 to 8.3 suggesting soils are slightly origin to alkaline. The soils are very low in soluble salt concentration with EC values ranging from 0.07 to 0.2 dsm⁻¹ and organic carbon content of soils ranged from 2.1 to 8.59 g kg⁻¹. The soils had high calcium carbonate ranging from 50 to 248 g kg⁻¹, Cation exchange capacity of soils varies from 26.6 to 57.1 cmol (p⁺) kg⁻¹ and the base saturation percentage was 88.0 to 97.1 per cent.

Ravte (2008) analyzed the soils of AUSA and Nilanga tahsils of Latur district and reported that the Ca^{++} content in these soils is ranged from 11.05 to 50.7 cmol (p+) kg⁻¹, and the Mg^{++} content in these soils is ranged from 20.6 to 28.9 cmol (p+) kg⁻¹, respectively.

Cheke *et al.* (2014) studied the Entisols, Inceptisols and Vertisols soils of Lohara tahsil in Osmanabad district of Maharashtra and reported that soils were alkaline in reaction and within safer limits of electrical conductivity. These soils were calcareous in nature, low to medium in organic carbon content.

Sekhar *et al.* (2014) studied on genesis characterization and classification of soils of central and eastern part of Prakasam district of Andhra Pradesh and observed that soil pH was ranged from 6.02 to 8.45 which was slightly acidic to slightly alkaline in nature, electrical conductivity values varied from 0.01 to 0.34 dsm⁻¹, organic carbon content of these soils ranged from 0.12 to 0.68 per cent, CEC of all pedons were varied from 3.48 to 48.74 cmol (p+) kg⁻¹, free CaCO_3 ranged from 4.57 to 13.44 per cent, the base saturation varied from 73.44 to 91.52.

Mane *et al.* (2015) revealed that the grape growing soils of Osmanabad district were slightly to moderately alkaline in reaction with pH ranged from 7.1 to 8.3. The electrical conductivity ranged between 0.10 to 0.68 dSm⁻¹. The organic carbon content in these soils varied from 0.10 to 2.07 per cent and calcium carbonate ranged between 1 to 42.9 per cent, indicating that soils were calcareous in nature. The CEC of soils varied from 18.20 to 62.0 cmol (p+). The exchange site was the dominance of calcium followed by magnesium, sodium and potassium in all profiles. The base saturation per cent varied from 90.21 to 97.9 per cent.

Malavath and Mani (2015) studied on cotton growing soils in semi and tropics of Tamil Nadu and found that the pH of these soils was moderately alkaline to strongly alkaline (8.48 to 9.13). The electrical conductivity of pedons ranged from 0.14 to 0.72 dsm⁻¹, organic carbon status between (5.4 to 5.5 gm kg⁻¹) and the CaCO_3 content varied from 7.3 to 15.5 per cent. The exchangeable cation capacity was high (44.6 to 48.8 cmol (p+) kg⁻¹).

Vaidya and Dhawan (2015) studied degraded land hybridization with tank silt impact on soil quality and productivity of soybean and reported that soils were neutral to alkaline in pH and varied from 7.1 to 7.7. The electrical conductivity was $< 0.25 \text{ dsm}^{-1}$ and the CEC of surface horizon of hybridized soils varied from 37.6 to $57.9 \text{ c mol (p}^+) \text{ kg}^{-1}$ and base saturation varied from 80-94 per cent.

Jyothi and Hebsur (2016) studied evaluation of fertility status of selected Bt. cotton growing soils of Northern transitional zone of Karnataka and observed that the pH of vertisol soils of cotton growing were varied from 7.64 to 8.54 and in alfisol soils pH varied from 5.63 to 7.92. The electrical conductivity values ranged from 0.52 to 0.94 dsm^{-1} and organic carbon content in the surface soil was 5.45 to 6.85 g kg^{-1} .

Aundhakar *et al.* (2018) studied on cotton growing soils of Beed district and stated that soils were slightly to moderately alkaline in nature (7.2 to 7.8). The electrical conductivity varied from 0.1 to 0.5 dsm^{-1} , low to high in organic carbon (0.4 to 0.9). The CaCO_3 present in these soils were 4.56 to 23.19% and high in cation exchange capacity (36.07 to $80.57 \text{ cmol (p}^+) \text{ kg}^{-1}$). The base saturation percentage was 78.82 to 97.79 per cent.

Ghode *et al.* (2018) studied on characterization classification and evaluation of cotton growing soils of Nanded district and stated that the soils are slightly to moderately alkaline in nature (pH 7.2 to 8.5), the electrical conductivity varied from 0.1 to 0.4 dsm^{-1} , low to high in organic carbon (0.1 to 0.9 %) where as low to very high in calcium carbonate content in soils (5.3 to 36.1%), high cation exchange capacity (35.40 to $66.30 \text{ cmol (p}^+) \text{ kg}^{-1}$). The base saturation percentage was 74.89 to 99.70 percent.

Ingole *et al* (2018) studied on effect of moisture and calcium carbonate content on chemical properties of soil and yield of cotton in Nanded district and observed that the soils were slightly to moderately alkaline in nature with pH ranged from 7.4 to 8.1 at 0-30 cm depth where as 7.6 to 8.4 at 30-60 cm depth. The electrical conductivity ranged from 0.1 to 0.3 dsm^{-1} at 0-30 cm depth and 0.2 to 0.4 dsm^{-1} at 30-60 cm depth. The organic carbon content of studied soils varied from 0.32 to 0.89 per cent at 0-30 cm depth where as it was 0.26 to 0.80 per cent at 30-60 cm depth. The

calcium carbonate content in studied soil varied from 9.4 to 29.4 per cent at 0-30 cm depth where as 6.1 to 32.9 per cent at 30-60 cm depth.

Satish *et al.* (2018) studied the characterization and classification of the soils of Brahmanakotpur watershed of Andhra Pradesh and found that the soils were neutral to strongly alkaline (pH 7.01 to 8.86), non saline in nature and electrical conductivity ranged from 0.10 to 0.58 dsm^{-1} , organic carbon ranged from 0.10 to 5.8 g kg^{-1} and cation exchange capacity of soil varied from 8.11 to 61.72 $\text{cmol (p}^+) \text{kg}^{-1}$ and the base saturation ranged from 69.1 to 99.1 per cent.

Ingle *et al.* (2019) studied the physico-chemical properties of soils of Kanholibara village in Nagpur district and found that the soils were low to moderately alkaline (7.55 to 8.1), electrical conductivity varied from 0.61 to 1.83 dsm^{-1} , organic carbon content (0.70 to 1.46 g kg^{-1}) was moderate to high.

Kalyani *et al.* (2019) studied on effect of organic sources on physico-chemical properties of soil and uptake of nutrients in cotton under rainfed condition and observed that the significantly lowest pH at surface and subsurface soils 7.81 and 7.91. The electrical conductivity 0.11 to 0.12 dsm^{-1} was observed respectively. The treatment 10 t ha^{-1} FYM showed significant improvement of organic carbon content of soils at surface (6.04 g kg^{-1}) and subsurface (5.64 g kg^{-1}).

Magare *et al.* (2019) studied the physico chemical characteristics and available micro and secondary nutrients in soils of agro ecological sub region of Latur district and reported that the soil samples were neutral to moderately alkaline in reaction (7.5-8.3), electrical conductivity were non saline (0.12 to 0.33 dsm^{-1}), low to moderately high in organic carbon (3.86 - 7.54 g kg^{-1}) and calcium carbonate ranged from (4.25-8.13%) and showed soils were moderately calcareous in nature.

Ingle *et al.* (2020) Investigated on the effect of different resource conservation practices on soil chemical properties under cotton cultivation and found that the pH of soil ranged from 8.29 to 8.34. The electrical conductivity varied from 0.14 to 0.17 dsm^{-1} and organic carbon content under cotton cultivation ranged from 5.97 to 6.20 gm kg^{-1} .

Thale *et al.* (2020) studied characterization classification and soil site suitability of pomegranate growing soils of Laur district and stated that the soils were slightly to strongly alkaline in nature (pH 7.58 to 8.92). The electrical conductivity of soil was less than 1 dsm^{-1} ; organic carbon content in soil was very low to high (0.37 to 0.84 per cent). Soils were calcareous in nature (4.2 to 15.26%).

Wahane *et al.* (2020) studied cotton-based cropping system in relation to land forms and soil properties in a micro watershed and observed that the soils were moderately acidic to moderately alkaline (pH 5.5 to 8.5) in nature. Electrical conductivity of the soils found in low range 0.05 to 0.11 dsm^{-1} , organic carbon content ranged from 0.23 to 0.75 per cent. The CaCO_3 content in soil ranged from 10.66 to 21.46 per cent, cation exchange capacity showed variation in all the soil profiles and ranged from 29.76 to 63.36 $\text{cmol}(\text{p}^+) \text{ kg}^{-1}$. Base saturation ranged from 32.49 to 99.27 per cent.

2.4 Nutrient's status of soil

2.4.1 Available Macronutrients

Mandal *et al.* (2005) studied *i.e.*, from 1990 to 1992 (all the three years), centenary swell shrinks' soils of Nagpur at different depths and found to contain exchangeable calcium ranged from 18.50 to 39.34 $\text{cmol}(\text{p}^+) \text{ kg}^{-1}$ soil.

Mandal *et al.* (2005) during the period of study *i.e.*, from 1990 to 1992 (all the three years), centenary swell shrinks' soils of Nagpur at different depths found to contain exchangeable magnesium ranged from 8 to 21.43 $\text{cmol}(\text{p}^+) \text{ kg}^{-1}$ soil.

More *et al.* (1987) reported that the exchangeable calcium in soils of Purna command ranged from 11.80 to 22.50 $\text{cmol}(\text{p}^+) \text{ kg}^{-1}$.

More *et al.* (1987) reported that the exchangeable magnesium in soils of Purna command ranged from 6.70 to 15.63 $\text{cmol}(\text{P}^+) \text{ kg}^{-1}$.

Gaikwad and Tangadge (1993) studied physico-chemical properties of Typic Chromusterts in Granitic Terrian and observed that exchangeable Mg ranged from 0.3 to 20 $\text{cmol}(\text{p}^+) \text{ kg}^{-1}$.

Jagdish Prasad *et al.* (2001) characterised and classified four typical shrink-swell orange supporting soils of Nagpur district. The Selu and Nimji soils were well drained, very shallow and shallow in depth underlain by weathered basalt while Gondkhairi (p3) and Gondkhairi (p4), were both deep, but moderately well-drained and imperfectly drained, respectively. It was found that exchangeable calcium ranged from 24.1 to 42.5 cmol (p⁺) kg⁻¹.

Sharma and Bhaskar (2003) explored the physical and chemical characteristics of eleven soil series identified during reconnaissance survey of Rajkot district in Gujarat state were used to measure the soil variability in five geomorphologically defined survey units and then to assess their similarities for subsequent identification of soil subgroups. It was revealed that exchangeable Mg ranged from 3.0 to 18.6 cmol (p⁺) kg⁻¹

Kawde *et al.* (2005) studied physico-chemical properties and classified salt affected soils of Keliveli (dist. Akola) from Purna valley. The soil samples of 5 pedons from Keliveli were collected to interpret the nature of salt affected soil. It was reported that exchangeable calcium content in soils of Keliveli, district Akola varies from 18.2 to 35.2 cmol (p⁺) kg⁻¹.

Gabhane *et al.* (2006) selected fourteen pedons based on the variation in the soil-site characteristics and studied for production potential and land use planning of Belura watershed in Akola district of Vidarbha region of Maharashtra. It was noticed that the exchangeable Mg ranged from 9.0 to 21.48 cmol (p⁺) kg⁻¹ in different horizons.

Hundal *et al.* (2006) studied available nutrient and heavy metal status of soils of Punjab, North West India. It was reported that concentration of available dominating cations calcium and magnesium in soils of Punjab and North West India generally occurred between 3.16 to 316 mg kg⁻¹.

Meena *et al.* (2006) investigated the status of the macro and micronutrients in some soils of tank district of Rajasthan and reported that the available nitrogen content varied from 125 to 555 kg ha⁻¹. The available phosphorus content varied from 9.2 to 65.2 kg ha⁻¹ and available potassium in the soils was ranged from 105 to 1059 kg ha⁻¹.

Balpande *et al.* (2007) studied the Grape growing soils in Nashik district of Maharashtra and indicated that the exchangeable Mg ranged from 2.16 to 20.0 cmol (P⁺) kg⁻¹ in different horizons.

Tripathi and Sawarkar (2007) morphologically studied characterized and classified four vertisol pedons in Jabalpur district, Madhya Pradesh, India. It was observed that the exchangeable calcium content in these soils ranged from 20.1 to 37.07 cmol (p⁺) kg⁻¹.

Tripati and Sawarkar (2007) studied four Vertisol pedons in Jabalpur district, Madhya Pradesh, India, characterized and classified and observed that the exchangeable Mg content in these soils ranged from 6.3 to 18.60 cmol (p⁺) kg⁻¹.

Ravte (2008) analyzed the soils of Ausa and Nilanga tahsils of Latur district and reported that the Ca content in these soils ranged from 11.05 to 50.7 cmol (p⁺) kg⁻¹ respectively.

Ravte (2008) analyzed the soils of Ausa and Nilanga tahsils of Latur district and reported that the Mg content in these soils ranged from 20.6 to 28.9 cmol (p⁺) kg⁻¹ respectively.

Ravte (2008) analyzed the soils of Ausa and Nilanga tahsils of Latur district and reported that the available S content in these soils ranged from 3.62 to 84.61 mg kg⁻¹ respectively.

Rashmi *et al.* (2009) studied physico-chemical properties of paddy growing soils of upper Krishna project in Karnataka. The study was undertaken in Shorapur taluk of upper Krishna command (UKP) to know the impact of paddy cultivation on soil properties. The data showed exchangeable Ca of pedon samples and auger samples was spread between 7.0 to 31.4 and 10.01 to 23.90 cmol (P⁺) kg⁻¹ respectively of paddy growing soils of upper Krishna project in Karnataka.

Rashmi *et al.* (2009) studied physico-chemical properties of paddy growing soils of upper Krishna project in Karnataka. The study was undertaken in Shorapur taluk of upper Krishna command (UKP) to know the impact of paddy cultivation on soil properties. It was showed exchangeable Mg of pedon samples and

auger samples was spread between 3.0 to 18.50 and 3.99 to 9.10 cmol (P⁺) kg⁻¹ respectively of paddy growing soils of upper Krishna project in Karnataka.

Alane (2010) studied on physico-chemical characteristics and nutrient status of soils from Aundha and Kalamnuri tehsil of Hingoli district and showed that 0.46 % organic carbon from Aundha and 0.45 % average organic carbon content from Kalamnuri.

Sahoo *et al.* (2010) evaluated eight representative soil profiles from different landforms *viz.* high hill, medium hill, low hill and foot hill slopes of Langol hill, Imphal, Manipur were studied and observed that the exchangeable Mg ranged from 0.45 to 9.74 cmol (p⁺) kg⁻¹ in different horizons of soils of Langol hill, Manipur.

Bacchewar and Gajbhiye (2011) studied correlation of secondary nutrients and soil properties in soils of Latur District of Maharashtra. Status of secondary nutrients and effect of soil properties on their status were studied in some soils from Latur district. Available Ca contents ranged from 13.0 to 52.0 Cmol (p⁺) kg⁻¹ with mean values of 37.8 Cmol (p⁺) kg⁻¹. The soil samples from Latur district showed high content of exchangeable Ca.

Bacchewar and Gajbhiye (2011) studied correlation of secondary nutrients and soil properties in soils of Latur District of Maharashtra. Status of secondary nutrients and effect of soil properties on their status were studied in some soils from Latur district. Available Mg contents ranged from 7.0 to 36.0 Cmol (p⁺) kg⁻¹ with mean values of 20 Cmol (p⁺) kg⁻¹. The soil samples from Latur district showed high content of exchangeable Mg.

Cheke (2012) studied on status of available nutrients in soils of Lohara tahsil of osmanabad district and reported that, these soils were calcareous in nature and contents low to medium organic carbon. According to nutrient index value the soils of lohara tahsil were low in available N, P, S and Zn, while high with respect to available k. The Caco₃ showed negative correlation with available S.

Medhe *et al.* (2012) studied correlation of chemical properties, secondary nutrients and micronutrient anions from the soils of Chakur tahsil of Latur district Maharashtra. Hundred soil samples from Chakur tahsil of Latur district (M.S.)

were collected and analyzed for its chemical properties, secondary nutrients and micronutrient anions. The exchangeable Ca^{++} varied from 18.4 to 54.4 Cmol kg^{-1} .

Medhe *et al.* (2012) studied correlation of chemical properties, secondary nutrients and micronutrient anions from the soils of Chakur tahsil of Latur district Maharashtra. Hundred soil samples from Chakur tahsil of Latur district (M.S.) were collected and analyzed for its chemical properties, secondary nutrients and micronutrient anions. The exchangeable Mg^{++} varied from 8.7 to 29.7 $\text{Cmol (p}^+) \text{kg}^{-1}$.

Ramesh babu and Gurumurthy (2012) studied physico chemical properties and available nutrients under paddy land use cover of Thirthahalli taluk of Shimoga district. The 150 surface soil samples from different villages were collected, processed and analyzed for various parameters. The exchangeable Ca content found to be varied from 4.87 $\text{Cmol (p}^+) \text{kg}^{-1}$.

Ramesh Babu and Gurumurthy (2012) studied physico chemical properties and available nutrients under paddy land use cover of Thirthahalli taluk of Shimoga district. The 150 surface soil samples from different villages were collected, processed and analyzed for various parameters. The exchangeable Mg content found to be varied from 2.47-2.7 $\text{Cmol (p}^+) \text{kg}^{-1}$.

Ghodke (2014) Assesment of Fertility status of Southern tehsils of Parbhani district (Sonpeth, Gangakhed and Palam) was low to medium in organic carbon with calcarerus in nature. The pH shows negative corelation in available P. S. Fe, Mn, Zn and Cu in the soils.

Mandavgade (2014) studied on Evaluation of nutritional status of Northern tahsils of Parbhani district (Jintur, Selu and Pathri) and reported that, low to medium organic carbon with non-calcareous to calcareous in nature. Available N and Zn nutrients are in low range.

Sunewad (2014) Studies on fertility Status of Central tehsils of Parbhani District (Manwat, Parbhani and Purna) and reported that moderately alkaline in soil reaction. The organic carbon content of Central tehsils of Parbhani district ranged from low to medium, varied from 0.32 to 0.69 per cent. The calcium carbonate content showed negative correlation with available P and DTPA Zn.

Waikar *et al.* (2014) reported that the available phosphorus in soils of Jintur varied from 9.26 to 23.97 kg ha⁻¹ with an average value of 14.67 kg ha⁻¹, in Selu phosphorus varied from 7.20 to 23.37 kg ha⁻¹ with mean value of 12.78 kg ha⁻¹ and from Pathri ranged from 7.31 to 24.61 kg ha⁻¹ with an average value of 14.79 kg ha⁻¹.

Chadar (2017) Studies on the Changes on Soil quality Status of College of Agriculture, Latur Farm and Preparation of Soil site Suitability map and reported that as depth increased the per cent organic carbon was increased and soils were low to moderate in organic carbon content.

Mandavgade *et al.* (2015) reported that DTPA extractable Zn varied from 0.07 to 1.29 mg kg⁻¹ with mean value of 0.43 mg kg⁻¹ in Jintur tehsil, 0.11 to 3.16 mg kg⁻¹ with mean value of 0.41 mg kg⁻¹ in Selu and 0.04 to 1.72 mg kg⁻¹ with mean value of 0.88 mg kg⁻¹ from Pathri tehsil of Prabhani district.

Vaidya and Dhawan (2015) studied degraded land hybridization with tank silt impact on soil quality and productivity of soybean and stated that the available nitrogen varied from 230 to 313 kg ha⁻¹. The available phosphorus from 10.7 to 17.8 kg ha⁻¹ and the available potassium varied from 287 to 481 kg ha⁻¹.

Adkine (2016) studied on Evaluation of soil and ground water quality of the Krishna valley in Marathwada region of Maharashtra for land use planning and reported that the soils were slightly to moderately alkaline (pH 7.10 to 8.27) in reaction, low to medium in organic carbon content 0.09 to 0.93 per cent and calcareous in nature 0.92 to 23.11 per cent.

Jyothi and Hebsur (2016) studied the evaluation of fertility status of selected *Bt* growing soils of Northern transitional Zone of Karnataka and reported that the available N, P and K present in the soil varied from 101.80 to 270.20 kg ha⁻¹, 19.60 to 40.29 kg ha⁻¹ and 245 to 551 kg ha⁻¹ respectively.

Adat *et al.* (2017) studied on fertility status of Hingoli and Sengaoon Tehsil and reported that available nitrogen content from soils of Hingoli were ranged from 105.62 to 457.85 kg ha⁻¹ and soils of Sengaoon tehsil varies in available nitrogen from 112.88 to 313.60 kg ha⁻¹ with average value of 216.42 kg ha⁻¹. From Hingoli tehsil 94 per cent soils were low and 6 per cent were placed in medium category in

available N content whereas 92 per cent soils were low and 8 per cent were medium in available N content from Sengaon tehsil.

Sutar (2017) studied on Characterization, Classification and Evaluation of Physiography of Soils of Zari-Naam River Watershed (Part-3) of Parbhani District by Using GIS, GPS and Remote Sensing and reported that the soils were showed variation in fertility status. In general majority of soil samples were categorized as low in N and high in K.

Ingole *et al.* (2018) studied on effect of moisture and calcium carbonate content on chemical properties of soil and yield of cotton in Nanded district and observed that the available nitrogen content in the cotton growing soil at 0-30 cm depth was varied from 128.69 to 185.6 kg ha⁻¹ where as 88.5 to 165.2 kg ha⁻¹ at 30-60 cm depth. The available phosphorus at 0-30 cm depth was varied from 8.3 to 21.7 kg ha⁻¹ and at 30-60 cm depth 4.1 to 17.3 kg ha⁻¹. The available potassium content in the soils varied from 251.3 to 537.8 kg ha⁻¹ at 0-30 cm depth and 102.4 to 384.2 kg ha⁻¹ at 30-60 cm depth. The available magnesium varied from 1116 to 2148 mg kg⁻¹ at 0-30 cm and 1163 to 2184 mg kg⁻¹ at 30-60 cm. The available sulphur content in studied soil ranged from 11.7 to 33.7 mg kg⁻¹ at 0-30 cm depth and 11.1 to 24.1 mg kg⁻¹ at 30-60 cm depth.

Ingle *et al.* (2019) studied the physico chemical properties of soils of kanholibara village in Nagpur district and found that the available nitrogen content of soils was varied from 185.44 to 300.0 kg ha⁻¹. The available phosphorus content of these soils varied from 15.65 to 19.45 kg ha⁻¹ and the available potassium content ranged from (178.80 to 330.8 kg ha⁻¹) whiles the available sulphur present in soils varied from 11.56 to 12.51 kg ha⁻¹.

Jangir *et al.* (2019) studied on status of available major and micro nutrients in soils of Kelapur block of Yavatmal district and found that the available nitrogen present in the soil varied from 50.2 to 197.6 kg ha⁻¹. The available phosphorus varied from 0.7 to 50.4 kg ha⁻¹ and the available potassium present in the studied area was ranged from 140 to 336 kg ha⁻¹.

Magare *et al.* (2019) studied the secondary nutrients in the soils of agro ecological sub regions of Latur district and reported that exchangeable Ca (14.65 -

31.45 c mol (p⁺) kg⁻¹) and Mg (12.12-27.65 c mol (p⁺) kg⁻¹) with mean of 23.32 and 20.63 c mol (p⁺) kg⁻¹ respectively and found sufficient available sulphur ranged from 10.18 to 14.58 with mean of 12.43 mg kg⁻¹.

Ingale *et al.* (2020) studied on effect of different resource conservation practices on soil chemical properties under cotton cultivation and observed that the available N content in cotton cultivated soil ranged from 209.20 to 225.90 kg ha⁻¹ and the available phosphorus after harvest of cotton in soils was ranged from 14.92 to 16.80 kg ha⁻¹.

Purandhar and Naidu (2020) studied on characterization classification and fertility status of soils of Puttur Mandal in Chittoor district, Andhra Pradesh and observed that soils were low to medium in available nitrogen (56.2 to 477.7 kg ha⁻¹) low to high in available phosphorus (7.6 to 90.8 kg ha⁻¹). The available potassium ranged from (137.7 to 442.0 kg ha⁻¹) and deficient to sufficient in available sulphur (1.7 to 40 mg kg⁻¹) content.

2.3 Fertility status of soil

2.4.2 Available micronutrients

Meena *et al.* (2006) studied the status of micronutrients in some soils of tank district of Rajasthan and reported that the content of Zn, Fe, Cu and Mn varied from 0.19 to 1.93, 2.23 to 14.16, 0.21 to 1.87 and 6.85 to 45.25 mg kg⁻¹ respectively.

Shinde (2007) reported that DTPA extractable micronutrients includes Zn, Fe, Mn and Cu of surface layer of Deoni tahsil of Latur district varied from 0.14 to 2.98, 0.52 to 15.64, 0.14 to 11.54 and 0.70 to 9.06 mg kg⁻¹ respectively.

Mandavgade *et al.* (2015) stated that the DTPA Cu content varied from 0.75 to 6.54 mg/kg with average value of 2.55 mg kg⁻¹ in soils of Jintur tahsil, 0.55 to 3.02 mg kg⁻¹ with mean value of 1.55 mg kg⁻¹ in the soils of Selu tahsil and 0.11 to 3.98 mg kg⁻¹ with mean value of 1.40 mg kg⁻¹ in soils of Pathri tahsil.

Jyothi and Hebsur (2016) studied the evaluation of fertility status of selected *Bt* cotton growing soils of northern transition zone of Karnataka found that the DTPA extractable zinc content in the soils varied from 0.23 to 0.47 mg kg⁻¹. Iron

content ranged from 7.36 to 12.31 mg kg⁻¹. The Mn present in soil ranged from 1.39 to 3.95 mg kg⁻¹ and copper content ranged from 1.02 to 3.76 mg kg⁻¹.

Ingole *et al.* (2018) studied on effect of moisture and calcium carbonate content on chemical properties of soil and yield of cotton in Nanded district and observed that the available micronutrients (Fe, Mn, Zn, Cu) content under cotton growing soils of Nanded district at square formation stage of cotton was varied from Fe (10 to 22.8), Mn (7.83 to 19.4), Zn (0.31 to 0.96) and Cu (1.46 to 5.81) mg kg⁻¹ in 0-30 cm soil depth where as Fe (9.5 to 21.5), Mn (5.4 to 18.8), Zn (0.23 to 0.81) and Cu (1.42 to 5.48) mg kg⁻¹ respectively in 30-60 cm soil depth.

Magare *et al.* (2019) studied that available micro and secondary nutrients in soils of agro ecological sub region of Latur district and observed that the DTPA extractable zinc, copper, iron, manganese, varies from (00.39 – 0.87), (3.61 – 10.08), (18.32 – 32.00) and (30.62 – 65.94) mg kg⁻¹ which mean of 0.56, 6.04, 28.69 and 46.98 mg kg⁻¹ respectively.

2.6 Correlation between physico-chemical properties and available nutrients of soil

Meena *et al.* (2008) studied the status of micro and micronutrients in some soils of tank district of Rajasthan and report that the significant positive correlation ($r = 0.639^{**}$) was found between organic carbon and available nitrogen. The significant positive co relation ($r = 0.797^{**}$) was found between organic carbon and available phosphorus. The significant positive co relation ($r = 0.420^{**}$) was found between organic carbon and available “K”.

Cheke (2012) the pH showed negative correlation with available K, Ca, Mg⁺⁺ and DTPA-Fe, Mn exchangeable and Zn, while significant and with available N. EC showed positive correlation established negative with available N, P and exchangeable Mg but it was significant with only available nitrogen. Organic carbon created correlation with available N, positive P, K, S, However, CaCO₃ exchangeable Mg⁺⁺, DTPA-Fe, Zn and Cu, showed negative correlation with available N, K, S, and Ca.

Pawar *et al.* (2014) evaluated soil quality for pomegranate in Osmanabad district of Maharashtra and observed that the relationship between cation exchange capacity and clay content in soil was found significantly positive ($r=0.93$).

Singh *et al.* (2014) studied the soil fertility status and co relation of available macro and micro nutrients in Chambal region of Madhya Pradesh and reported that the available phosphorus significant and negatively co related with EC ($r = -0.210$), CaCO_3 ($r = -0.181$) and pH ($r = -0.513$). The available nitrogen negatively and significant correlated with pH ($r = 0.210$), EC ($r = -0.28$) where as negative and non significant co relation ($r = -0.026$) with CaCO_3 . A significant positive correlation of available potassium with Organic carbon ($r = 0.426$), EC ($r = 0.221$) and silt plus clay ($r = 0.520$) available K showed negative co relation and non significant with pH ($r = -0.026$) and CaCO_3 ($r = -0.026$).

Waikar *et al.* (2014) stated that available P and S observed significant co relation with electrical conductivity. The significant positive co relation was observed between available potassium and electrical conductivity.

Mandavgade *et al.* (2015) studied the soil status of DTPA Fe, Mn, Zn, Cu in relation with chemical properties of soils of Pathri, Selu, Jintur of Parbhani district and stated that DTPA Mn was observed significantly co related with electrical conductivity. The negative co relation of available Zn with soil pH ($r = 0.036$).

Bhat *et al.* (2017) studied the soil samples of grape orchards of Kashmir and reported that the pH of surface soil showed that significant and negative correlation with nitrogen ($r = 0.722$) and phosphorus ($r = 0.599$) and significant and positive correlation with calcium ($r = 0.571$) soil surface organic carbon showed positive and significant correlation with available nitrogen ($r = 0.904$), phosphorus ($r = 0.856$), Sulphur ($r = 0.566$) and iron ($r = 0.592$).

Ingole *et al.* (2018) studied on effect of moisture and calcium carbonate content on chemical properties of soil and yield of cotton in Nanded district and observed that the DTPA extractable micronutrients Mn, Cu was found significant and negative co related with CaCO_3 content in the soil ($r = -0.85, -0.58$ respectively) and others are non-significant.

Ingole *et al.* (2018) studied on effect of moisture and calcium carbonate content on chemical properties of soil and yield of cotton in Nanded district and reported that the significant negative correlation between CaCO₃ content in soil and available nutrients viz. N, Mn, Mg, K, Cu and (r = -0.85), (r = -0.85), (r = -0.70), (r = -0.66), (r = -0.58), (r = -0.41) respectively.

Patangray *et al.* (2018) studied the soil nutrients and its co relation with chemical properties of soil and reported that the pH of soil showed non-significant and negative co relation with nitrogen (r = 0.36) non-significant and positive correlation with phosphorus (r = 0.06), potassium (r=0.11), Sulphur (r = 0.25) and significant and negative correlation with iron (r = -0.096), manganese (r = -0.097), zinc (r = -0.71) and copper (r = 0.89) soil organic carbon shows significant and positive co relation with nitrogen (r = 0.63) zinc (r=.61) and copper (r=0.51) where as it was non-significant and positive with all other nutrients calcium carbonate content of soil showed significant and negative correlation with nitrogen (r = -0.65), iron (r = -0.61) zinc (r = -0.60) and copper (r = -0.69).

Priyanka *et al.* (2018) studied on available nutrients status in black soils of Akola district and reported that the significant and positive co relation of available N and available P with organic carbon of (r = 0.988**) and (r = 0.421*) respectively. The available sulphur showed positive and significant relation with available N (r = 0.482*).

Mishra *et al.* (2019) studied the macro and micronutrients and their relationship with soil physico-chemical properties and stated that the significant positive co relation the available phosphorus and organic carbon (r= 0.11), pH (r = 0.149), EC (r = 0.169) and significantly negative co relation between bulk density and phosphorus i.e. (r = -0.057).

Ghode *et al.* (2020) studied the relationship between soil physico-chemical properties, available macro and micro nutrients and yield in cotton growing soils of Nanded district and observed that the pH of soils was non-significant negative correlation with nitrogen (r = -0.34), phosphorus (r = -0.21), potassium (r = -0.35), exchangeable calcium (r = -0.57) and exchangeable magnesium (r = -0.19) and significantly correlated with available iron (r = -0.97**). Electrical conductivity

showed non-significant and positive correlation with available phosphorus ($r = 0.06$), potassium ($r = 0.24$), Sulphur ($r = 0.35$), zinc ($r = 0.26$), copper ($r = 0.06$) and exchangeable magnesium ($r = 0.17$) and non significant and negative relationship with available N ($r = -0.19$), Mn ($r = -0.12$) exchangeable calcium ($r = -0.25$). The organic carbon of soils were showed positive relationship with available N, K exchangeable Ca exchangeable Mg, S, Fe, Cu, Zn ($r = 0.35$), ($r = 0.31$), ($r = 0.46$), ($r = 0.40$), ($r = 0.06$), ($r = 0.48$), ($r = 0.06$), ($r = 0.20$) respectively and negatively co related with P ($r = -0.24$), K ($r = -0.68$), S ($r = -0.49$), Fe ($r = -0.26$) and Zn ($r = -0.56$) and significantly negative co related with available nitrogen ($r = -0.84^{**}$) and exchangeable calcium ($r = -0.75^{**}$) and magnesium ($r = -0.89^{**}$) calcium carbonate showed positive relationship with available Mn ($r = 0.92^{**}$).

Purandhar and Naidu (2020) reported that the available nitrogen content showed as gradual decrease with soil depth following the depth distribution of organic carbon as significant and positive ($r = 0.395^*$) co relation between available nitrogen and organic carbon. The DTPA extractable Mn was revealed to soil organic carbon as positive and significant co relation ($r = 0.375^*$) between organic carbon and Mn.

CHAPTER – III

MATERIAL AND METHODS

CHAPTER – III

MATERIAL AND METHODS

The present investigation on the soils of Parbhani district was carried out to study the morphological, physical and chemical characteristics, nutrient status and correlation between physio-chemical properties and available nutrients of cotton growing soils.

In this chapter, details regarding the location of Parbhani district, site selection for surface and horizon wise sample collection for morphological, physical and chemical properties of soil.

The material used and procedure followed during this investigation are described under the following heads

3.1 Location and site

3.2 Climate and rainfall

3.3 Collection of soil sample

3.4 Preparation of soil samples

3.5 Method of soil analysis

3.6 Statistical analysis

3.1 Location and site

Geographically Parbhani district lies between 18°45' to 20°10' North Latitudes and 76°13' to 77°39' East Longitude. The district is bounded on the north by Hingoli and Buldhana districts. On the east by Nanded and Hingoli, on the South by Latur and on the West by Beed and Jalna district. Parbhani district covers an area of about 6250.58 km². The district is divided into 9 administrative subunits (Tehsils), namely, Parbhani, Gangakhed, Sonpeth, Pathri, Manwath, Palam, Sailu, Jintur and Purna.

The main river in the district is Godavari. The area is covered by basaltic lava rock. These layers are locally called Deccan Trap. It is formed from basic volcanic rocks of basaltic and dolerite rocks. In Parbhani district deep black soil, medium black soil, shallow black soil and light textured soils are found. The most of

the area is under the cultivation of cotton (*Gossypium spp.*), tur, soybean, sorghum and sugarcane in *Kharif* season and in the *Rabi* season wheat and gram are cultivated.

3.2. Climate and rainfall:

The climate of the Parbhani district is hot, dry semi-arid and characterized by mild winter and hot summer season which extends up to first week of June. The Parbhani district receives rains from South West monsoon during June to October. The mean annual rainfall is 873 mm in year 2020. Out of which 95 per cent (829.3 mm) is received during June to September. The winter season commences from November and last up to the end of February followed by summer season which continuous up to may. The mean maximum and minimum temperature were 35.9⁰C and 22.43⁰C respectively in April and may have high temperature up to 39.9⁰C and 40.9⁰C, December and January are coolest month (29.2⁰C and 29.7⁰C mean temperature). The length of growing period 149 days and humid period is 106 days soils has Ustic moisture regime and Hyperthermic temperature regime.

In Marathwada region, Parbhani district comes under tropical climate. Data on weekly weather parameters from 28th May 2020 to 27th May 2021 given on rainfall pattern, temperature and humidity variation during the period of 2020-2021 and recorded at meteorological observatory, VNMKV, Parbhani are tabulated in Table 3.1. The data indicated that during 2020-2021, the maximum temperature was recorded in the 21th meteorological week i.e., 43.7⁰C, whereas, minimum temperature was recorded in the 1st meteorological week i.e., 27^o C. The data on relative humidity was maximum in the 38th meteorological week i.e., 95 Per cent and minimum was in the 16th meteorological week that is 17 Per cent.

Fig 3.1 Climatic data and water balance of Parbhani district of Marathwada region in Maharashtra.

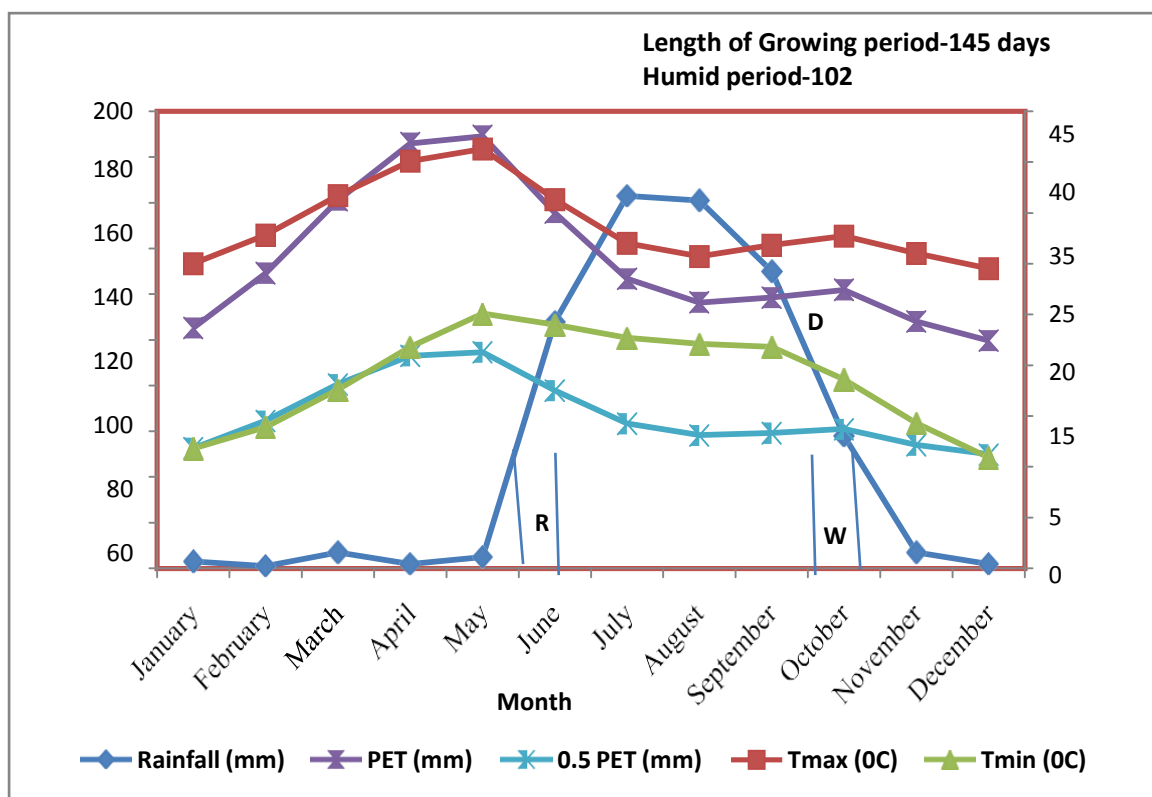


Table 3.1: Weekly weather data recorded at meteorological observatory, Vasantao Naik Marathwada Krishi Vidyapeeth, Parbhani during the experimental year 2020-21.

Week	Rainfall	Temperature °C		Humidity (%)		EVP (mm)	BSS (Hrs.)	WS (Kmph)
		Max	Min	RH1	RH2			
1	3.4	27.0	15.0	83	52	2.7	5.7	4.1
2	0.0	28.0	12.9	78	43	3.3	6.9	3.4
3	0.0	29.0	13.9	78	42	3.2	7.8	3.4
4	0.0	31.2	13.8	81	33	4.1	8.9	3.1
5	1.3	28.9	13.7	77	40	4.3	8.1	5.2
6	0.0	28.6	16.5	75	50	3.5	5.6	5.1
7	0.0	31.5	13.1	78	31	5.0	8.8	3.6
8	0.0	33.6	14.3	78	24	7.0	9.5	3.7
9	0.0	33.0	12.3	66	24	6.1	8.0	3.3
10	9.0	32.9	15.9	75	30	7.7	8.9	4.2
11	2.8	34.3	17.8	67	27	7.3	9.2	4.1
12	8.8	35.3	16.8	71	23	7.0	9.2	3.7
13	36.8	37.1	20.5	74	25	7.5	9.1	5.5
14	0.0	37.7	20.6	70	25	3.8	9.7	3.8
15	0.0	39.1	20.0	61	18	3.8	9.8	3.8
16	0.0	40.4	23.4	54	17	9.3	9.6	3.9
17	0.0	40.4	21.7	55	19	9.7	10.7	4.5
18	0.0	41.4	22.9	51	18	10.6	10.1	4.2
19	0.0	40.8	24.9	46	17	12.8	10.1	5.0
20	13.0	40.4	24.9	62	24	9.3	7.0	5.0
21	0.0	43.7	24.6	48	15	12.7	10.3	5.4
22	13.6	38.8	25.7	56	31	12.3	9.6	6.5
23	5.0	36.1	23.3	71	36	8.8	8.2	7.6
24	148.0	32.0	23.4	85	64	3.6	4.1	5.0
25	9.2	33.1	23.7	84	61	3.7	3.5	5.5
26	23.7	34.5	24.0	87	54	5.2	7.2	4.1
27	63.0	32.5	23.4	85	68	4.1	4.8	4.7
28	103.4	32.5	23.0	84	61	3.7	6.5	4.1
29	31.4	31.1	22.9	85	72	3.8	4.8	3.5
30	30.1	31.4	22.9	84	64	4.0	6.4	3.0
31	36.1	31.9	23.1	80	67	4.1	6.4	2.8
32	29.2	30.6	22.5	86	68	3.7	3.9	4.3
33	42.5	27.8	22.0	94	82	1.5	0.4	4.0
34	28.8	30.2	21.7	92	70	2.1	3.6	3.4
35	24.2	31.1	21.6	91	64	3.3	5.9	3.6
36	19.8	33.6	22.1	86	54	4.9	8.1	2.8
37	53.2	31.8	22.2	91	64	3.7	5.8	3.1
38	198.2	31.2	22.3	95	75	2.0	2.7	3.1
39	47.2	30.4	22.1	90	64	3.2	4.0	3.1
40	17.0	33.4	21.0	90	49	4.9	7.5	3.9
41	85.6	31.3	21.7	89	66	3.4	4.0	2.6
42	8.0	31.4	21.9	91	58	3.5	5.0	4.2
43	6.4	32.1	20.7	90	47	3.7	8.8	2.5
44	0.0	32.5	15.6	86	29	4.8	7.8	1.9
45	0.0	31.0	10.9	85	22	5.3	9.2	2.8
46	0.0	32.0	14.8	84	35	4.8	9.3	3.1
47	0.0	32.2	17.2	83	43	4.2	8.2	2.5
48	0.0	29.7	15.2	80	41	4.7	6.6	4.8
49	0.0	31.0	9.2	86.6	27.0	4.8	9.3	2.9
50	0.0	30.3	14.8	83.1	34.9	4.1	7.2	2.8
51	0.0	28.8	10.2	89.0	36.0	4.0	7.9	2.9
52	0.0	28.9	9.5	87.4	33.4	4.0	8.3	2.5

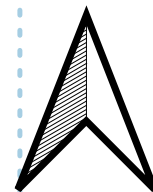
76°30'0.0"E

77°0'0.0"E

20°0'0.0"N

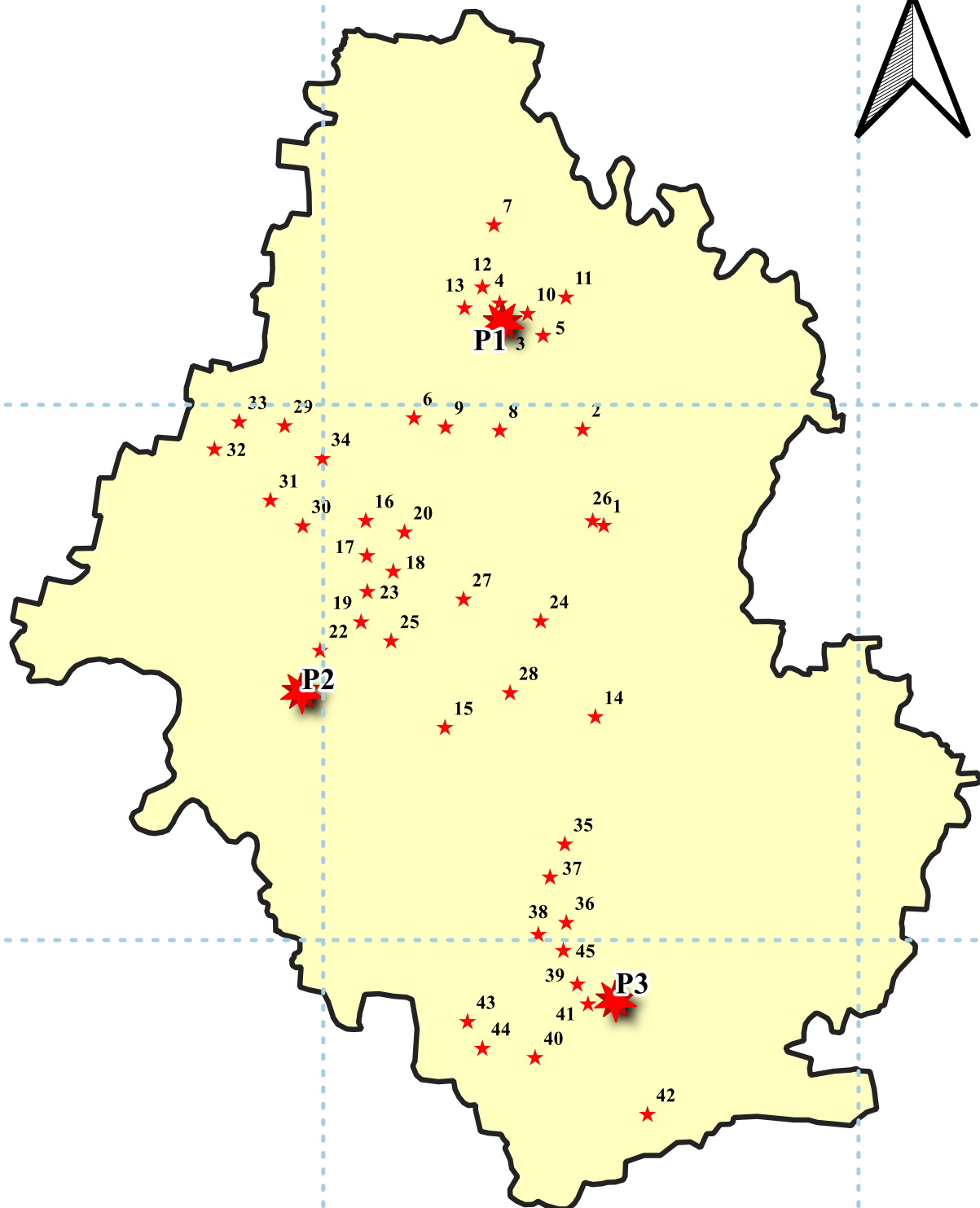
20°0'0.0"N

Location map of soil profiles and surface samples of Parbhani district



19°30'0.0"N

19°30'0.0"N



19°0'0.0"N

19°0'0.0"N

Legend



Pedon



Soil sample



Boundry

0 10 20 km



76°30'0.0"E

77°0'0.0"E

Table 3.2: Soil samples collected from study area of cotton growing soils of Parbhani district with G.P.S Readings.

Sample No.	Village	Latitude	Longitude
1	Zari	19 ⁰ 23' 13.6"	76 ⁰ 45' 42.9"
2	Bori	19 ⁰ 28' 36.2"	76 ⁰ 44' 32.1"
3	Balsa	19 ⁰ 34' 33"	76 ⁰ 40' 18"
4	Akoli	19 ⁰ 35' 41"	76 ⁰ 39' 53"
5	Pangri	19 ⁰ 33' 52"	76 ⁰ 42' 19"
6	Walur	19 ⁰ 29' 15"	76 ⁰ 35' 05"
7	Bhosi	19 ⁰ 40' 04"	76 ⁰ 39' 34"
8	Kausadi	19 ⁰ 28' 32.8"	76 ⁰ 39' 53.4"
9	Gulkhand	19 ⁰ 28' 44.2"	76 ⁰ 36' 51"
10	Mathala	19 ⁰ 35' 06"	76 ⁰ 41' 27"
11	Pungla	19 ⁰ 36' 01"	76 ⁰ 43' 36"
12	Warud	19 ⁰ 36' 35"	76 ⁰ 38' 55"
13	Malegaon	19 ⁰ 35' 25"	76 ⁰ 37' 55"
14	Taroda	19 ⁰ 12' 30"	76 ⁰ 45' 15"
15	Bhosa	19 ⁰ 11' 54"	76 ⁰ 36' 49"
16	Irlad	19 ⁰ 23' 30.1"	76 ⁰ 32' 22.8"
17	Manwat Road	19 ⁰ 21' 31.7"	76 ⁰ 32' 26.8"
18	Kolhawadi	19 ⁰ 20' 39.1"	76 ⁰ 33' 55.2"
19	Hattalwadi	19 ⁰ 17' 49"	76 ⁰ 32' 07"
20	Narlad	19 ⁰ 22' 51"	76 ⁰ 34' 33"
21	Renapur	19 ⁰ 13' 12"	76 ⁰ 28' 22"
22	Ukkhadgaon	19 ⁰ 16' 13"	76 ⁰ 29' 49"
23	Rudhi	19 ⁰ 19' 31"	76 ⁰ 32' 28"
24	Jamb	19 ⁰ 17' 51.9"	76 ⁰ 42' 11"
25	Sawali	19 ⁰ 16' 45"	76 ⁰ 33' 48"
26	Gokulwadi	19 ⁰ 23' 28.8"	76 ⁰ 45' 06"
27	Kinhola	19 ⁰ 19' 5.3"	76 ⁰ 37' 51.5"
28	Babhulgaon	19 ⁰ 13' 51"	76 ⁰ 40' 28"
29	Digras khurd	19 ⁰ 28' 49"	76 ⁰ 27' 50"
30	Zodgaon	19 ⁰ 23' 12"	76 ⁰ 28' 51"
31	Dhanegaon	19 ⁰ 24' 38"	76 ⁰ 27' 02"
32	Rawalgaon	19 ⁰ 27' 30"	76 ⁰ 23' 54"
33	Waki	19 ⁰ 29' 02"	76 ⁰ 25' 17"
34	Kawadhhan	19 ⁰ 26' 58"	76 ⁰ 29' 57"
35	Daithana	19 ⁰ 05' 22.0"	76 ⁰ 43' 32.3"
36	Dusalgaon	19 ⁰ 00' 58.3"	76 ⁰ 43' 37.2"
37	Rumna Jawla	19 ⁰ 03' 30.9"	76 ⁰ 42' 42.5"
38	Mahatpuri	19 ⁰ 00' 18"	76 ⁰ 42' 03"
39	Gangakhed	18 ⁰ 57' 31"	76 ⁰ 44' 14"
40	pokharni walkya	18 ⁰ 53' 24"	76 ⁰ 41' 52"
41	Kasarwadi	18 ⁰ 56' 24.2"	76 ⁰ 44' 50"
42	Belwadi	18 ⁰ 50' 13"	76 ⁰ 48' 10"
43	Shendga	18 ⁰ 55' 25"	76 ⁰ 38' 05"
44	Ukhali kh.	18 ⁰ 53' 55"	76 ⁰ 38' 55"
45	Bhamarwadi	18 ⁰ 59' 24"	76 ⁰ 43' 27.2"

3.3 Collection of soil samples

In order to study the properties of soil 3, GPS based soil profile samples and 45 GPS based surface samples (0-30 cm) were collected from cotton growing soils of Parbhani district. Characteristics of the pedon and individual horizon was studied morphologically in the field as per the procedures laid out in USDA Soil Survey Manual (Soil Survey Staff, 2006).

3.4 Preparation of soil samples

Collected soil sample was mixed thoroughly, air dried in shade. After drying, a part of each sample meant for nutrient analysis was ground in wooden mortar, pestle and preserved in polythene bag with proper labelling for further estimation of nutrients. The precautions were taken in order to avoid contamination. Similarly, other part of each sample was ground with porcelain mortar pestle passed through 2 mm and 0.5 mm sieve and stored in polythene bags with proper labelling for subsequent (analysis) estimation of chemical characteristics i.e., macro and micronutrients.

3.5. Method of soil analysis

The analysis of soil samples was done by following standard procedures as given below.

3.5.1 Morphological properties of soil

Morphological properties of soil were studied in the field and profile descriptions were made as per the procedure suggested by USDA Soil Survey Manual (Soil Survey Staff, 2006) and field guide for soil survey NBSSS and LUP (2009).

3.5.2 Physical properties of soil:

3.5.2.1. Particle size distribution:

It was determined by International Pipette Method following the removal of organic matter, calcium carbonate, and free iron oxide sand (2000-50 m), silt (50-2 μm), and clay fraction (< 2 μm and < 0.2 μm) were separated using the size segregation procedure of Jackson (1979).

3.5.2.2. Bulk Density

It was determined by dry clod coating technique given by Blacke and Hartge (1986).

3.5.2.3. Hydraulic conductivity:

Soil sample was fully saturated and then leached with deionized water and hydraulic conductivity of soil was determined by constant head method as described by Richard (1954).

3.5.2.4. Soil moisture retention:

The moisture retention of soil and release behavior within the available range of 33 kPa to 1500 kPa were based on less than 2 mm soil sample using pressure plate and membrane apparatus (Richards, 1954).

3.5.2.5. Available water capacity:

$$(W_{\max} - W_{\text{dry}}) \times \text{BD} \times 10$$

$$1. \text{ AWC} = \frac{\text{-----}}{\text{DW}}$$

$$Z = \text{RD}$$

$$2. \text{ PAWC} = \text{AWC} \times z$$

$$Z = 0$$

Where, W_{\max} = gravimetric water content (g g^{-1}) at the upper soil water

Storage limits (0.33 bars). W_{dry} = gravimetric water content after the plant water

Extraction i.e., lower soil water storage limits (15 bars).

BD = bulk density of W_{\max} (0.33 bar)

RD = rooting depth

z = depth increment

DW = density of water (approximately 1g cm⁻³)

3.6.3 Chemical properties of soil

3.6.3.1. Soil reaction:

pH of 1:2.5 soils: water suspension was determined by using pH meter as per method described by Jackson (1979).

3.6.3.2. Electrical conductivity:

1:2.5 soils: water suspension as per the method described by Jackson (1979).

3.6.3.3 Calcium carbonate:

The calcium carbonate was estimated by rapid titration method as described by Piper (1950).

3.6.3.4. Organic carbon:

Modified Walkley and Black's rapid titration procedure was followed for estimating the organic carbon content (Jackson, 1958).

3.6.3.5. Cation exchange capacity:

It was estimated by soil screened through 2 mm sieve was saturated with 1N sodium acetate (pH 8.2). After removal of excess sodium acetate by washing with alcohol, the adsorbed sodium was extracted by washing with 1N ammonium acetate (pH 7.0) and the leachate was made up to known volume. Na⁺ present in the leachate were determined with a flame emission spectrophotometer (Richards, 1954).

3.6.3.6. Exchangeable cations:

Exchangeable calcium and magnesium were determined on less than 2 mm samples by leaching with 1N NaCl solution (Piper, 1966) and titrating the leachate with standard EDTA solution as per the method of Richards (1954). Exchangeable sodium and potassium were determined on less than 2 mm soil by leaching with 1N ammonium acetate (pH 7.0) solution. Na and K from the leachates were estimated by flame emission spectrophotometer (Jackson, 1958).

3.6.3.7. Available nitrogen:

This was determined by alkaline permanganate method by using Kel-plus distillation unit (Subbiah and Asija, 1956).

3.6.3.8. Available phosphorus:

Available phosphorus was determined by Olsen's method, reading was recorded using spectrophotometer (Jackson, 1967).

3.6.3.9. Available potassium:

Available potassium was determined by flame photometer using 1N Neutral ammonium acetate (pH 7.0) solution as an extractant as described by (Jackson, 1967).

3.6.3.10. Available micronutrients:

DTPA (0.005 M) extractable Fe, Mn, Zn and Cu was determined as the procedure outlined by Lindsay and Norvell (1978) using atomic absorption spectrophotometer.

3.7 Nutrient Index:

$$NIV = N_L + 2 * N_M + 3 * N_H / N_L + N_M + N_H$$

(N_L = low nutrient index, N_M = Medium nutrient index, N_H = High nutrient index).

3.8 Statistical analysis

Correlation study was undertaken to find out the relation between physical and chemical properties of soil with yield and leaf nutrient status in plants and as per procedure described by Panse and Sukhatme (1985).

CHAPTER – IV
RESULTS AND DISCUSSION

CHAPTER -IV

RESULTS AND DISCUSSION

The present investigation was undertaken on “Evaluation of soil quality under cotton growing soils of Parbhani district” during the year 2020-2021. In that, 3 profile and 45 surface soil samples (0-30 cm depth) were collected from cotton growing soils. The results obtained after analysis of soil samples are presented and discuss under the following heads

4.1 Soil site characteristics

4.2 Morphological properties of soil

4.3 Physical properties of soil

4.4 Chemical properties of soil

4.5 Fertility status of soil (Profile)

4.5.1 Available macronutrients

4.5.2 Available micronutrients

4.6 Soil Classification

4.7 Fertility status of soil (surface)

4.7.1 Physico chemical characteristics of soil

4.7.2 Available macronutrients

4.7.3 Available micronutrients

4.8 Correlation between physico-chemical properties and available nutrients of soil

4.9 Yield of cotton

4.10 Soil nutrient index

4.1 Soil site characteristics

Soil site characteristics such as location, landform, slope and erosion were also studied and recorded in Table 4.1

Table 4.1: Soil sites characteristic under cotton growing soils of Parbhani district.

Location	Latitude and Longitude	Land Form	Parent material	Slope (%)	Runoff	Drainage	Erosion
Pedpn -1 Margalwadi, Gangakhed, Parbhani.	76° 75' 56" N 18° 94' 75" E	Nearly levelled plain	Weathered Basalt	1-3	Medium	Moderately well drained	Moderate
Pedon-2 Maak, Jintur Parbhani.	76° 74' 49" N 19° 44' 71" E	Nearly levelled plain	Weathered Basalt	1-3	Medium	Moderately well drained	Moderate
Pedon-3 Zodgaon, Selu, Parbhani.	76° 46' 73" N 19° 38' 51" E	Nearly levelled plain	Weathered Basalt	1-3	Medium	Moderately well drained	Moderate

Table 4.2: Morphological properties of cotton growing soils of Parbhani District.

Horizon	Depth (cm)	Boundary	Matrix Colour	Texture	Structure	Consistency	Pores	Roots	Effervescence
Pedon 1: Sangram Hange, Margalwadi, Gangakhed, Parbhani (Calcic Haplustept)									
AP	0-16	cs	10YR 3/2	cl	fl sbk	s, fr,sssp	vfm, fm	vfm, fm	e
BW1	16-30	cs	10YR 3/2	cl	fl sbk	s,fr,sssp	vfm, fm	vfmfm	e
Cr	30+	cs	10YR 3/3	sl	fl gr	s, fi,nsns	cm	cfff	es
Pedon 2: Yashwant Deshmukh, maak, Jintur, Parbhani (Calcic Haplustert)									
Ap	0-22	cs	10YR3/3	cl	m1sbk	s,fr,sssp	vfm,fm	vfmfm	ev
Bw1	22-32	cs	10YR3/3	cl	m1sbk	s,fr,sssp	vfm,fm	vfmfm	ev
Bw2	32-50	cs	10YR3/3	cl	m1sbk	s,fr,sssp	fm	fmcf	ev
BSs1	50-90	cs	10YR3/3	cl	m1sbk	s,fr,sssp	cf	fmcf	ev
BSs2	90+	cs	10YR3/4	cl	m1sbk	s,fr,sssp	fm,cf	fmcf	ev
Pedon 3: Shubham Pawar, ZodgaonTq. Selu, Parbhani (Calcic Haplustert)									
Ap	0-18	cs	10YR3/3	c	m2 sbk	s,fm,vsvp	vfm,fm	vfmfm	es
Bw1	18-36	cs	10YR3/3	c	m2sbk	s,fm,vsvp	vfm,fm	vfmfm	ev
BW2	36-55	cs	10YR3/2	c	m2sbk	s,fr,vsvp	vfm,fm	ffcf	ev
Bss1	55-80	ai	10YR3/2	c	m2sbk	l,fr,sssp	vfm,fm	ff	ev
Bss2	80-100	ai	10YR3/2	c	m2abk	l,fr,nsnp	vfm,fm	ff	ev
Bss3	100+	ai	10YR3/1	c	m2abk	l,fr,nsnp	vfm,fm	ff	ev

4.2 Morphological properties of soil:

The morphological characteristics of different pedons were studied during present investigation are presented in Table 4.2

Soil morphology is the study of forms, structure and organization of soil and their characteristics under the field condition. Soils were studied only in field and can be evaluated at field examination of the soil profile. However, in laboratory soil samples were analyzed for further study. Soil description is based on classified soil in defined categories in the profile. Various soil horizons were studied and each horizon was observed and described in respect of various characteristics such as depth, color, texture, consistency etc. The morphological characteristics and properties of Pedon under study were presented and P₁ shows that, the soil is shallow and very dark brown to brown in color. The morphology of P₂ and P₃ indicates that the soils are deep. The pressure faces were not observed in P₁. The slickensides were slightly developed in pedon-2 and well in pedon-3. The soils were very dark grayish brown to brown. In pedon-1, the effervescence was slightly seen in P₂ and P₃, the effervescence was strong to violent when treated with 10% hydrochloric acid. The morphological characteristics of these pedons are described as below.

Pedon -1 (P₁)

Location	:	Margalwadi, Tq.Gangakhed, Dist. Parbhani
Land form and slope	:	3-4%, moderately sloping, and nearly level plain
Drainage	:	Well drained
Vegetation	:	Neem, Accasia and subabul
Parent material	:	Basalt
Climate	:	Hot, dry semi-arid
Classification	:	Calcic Haplustepts



Plate 4.1: Overall view of the pedon No-1



Plate 4.2: Land use and land form around pedon No-1



Plate 4.3: Overall view of the pedon No-2



Plate 4.4: Land use and land form around pedon No-2

Horizon	Description
Ap	0-16 cm, ---Very dark grayish brown (10YR 3/2); silt clay; fine, sub-angular blocky structure; soft, friable, slightly sticky, slightly plastic; very fine many, fine few pores; very fine many, fine few roots; slight effervescence; moderately alkaline (pH 7.35); clear smooth boundary.
Bw ₁	16-30 cm, ---Very dark grayish brown (10YR 3/2); clay loam; fine, sub angular blocky structure; soft, friable, slightly sticky, slightly plastic very fine many, fine few pores; very fine many, fine few roots; slight effervescence; moderately alkaline (pH 7.5); clear smooth boundary.
Cr	30+cm, ---Dark brown (10 YR 3/3); sandy loam; fine, granular structures friable, non-sticky, non-plastic; fine few, coarse few pores; fine few, coarse common roots; stong effervescence; moderately alkaline (pH 7.6); clear smooth boundary.

Pedon- 2 (P₂)

Location	:	Maak, Tq. Jintur, Dist.Parbhani
Land form and Slope	:	1-3%, moderately sloping, nearly level plain
Drainage	:	Moderately well drained
Vegetation	:	Neem, Mango
Parent material	:	Basalt
Climate	:	Hot, dry semi-arid
Classification	:	Calcic Haplusterts

Horizon	Description
Ap	0-22 cm, ---Dark brown (10 YR 3/3); clay loam; medium, weak, sub-angular blocky structure; friable, slightly sticky, slightly plastic; very fine many, fine many pores; very fine many, fine many roots; slight effervescence; moderately alkaline (pH 7.8); clear smooth boundary.



Plate 4.5: Overall view of the pedon No-3



Plate 4.6: Land use and land form around pedon No-3

- Bw₁ 22-32 cm, ---Dark brown (10 YR 3/3); clay loam; medium, sub-angular blocky structure; soft, friable, slightly sticky, slightly plastic; very fine many, fine many pores; very fine many, fine many roots; violent effervescence; moderately alkaline (pH 7.7); clear smooth boundary.
- Bw₂ 32-50 cm, ---Dark brown (10 YR 3/3); clay loam; medium, weak, sub-angular blocky structure; soft, friable, slightly sticky, slightly plastic; fine many pores; fine many roots; slight effervescence; moderately alkaline (pH 7.6); clear smooth boundary.
- Bss₁ 50-90 cm, dark brown (10 YR3/3); clay; medium, strong, sub-angular blocky structure, hard, friable; slightly sticky, slightly plastic; coarse few pores; fine many, fine many roots; violent effervescence; moderately alkaline (pH 8.1); clear smooth boundary.
- Bss₂ 90+ cm, ---Dark brown (10 YR3/4); clay loam; medium, strong, sub-angular blocky structure, friable; slightly sticky, slightly plastic; fine few, coarse few pores; very fine many, fine few roots; violent effervescence; alkaline (pH 8.5); smooth boundary.

Pedon- 3 (P₃)

- Location : Zodgaon, Tq.selu, Dist. Parbhani
- Land form and slope : 0-1%, level plain
- Drainage : Moderately drained
- Vegetation : Babul, Neem and jamun
- Parent material : Basalt
- Climate : Hot, dry semi-arid
- Classification : Calcic Haplusterts

Horizon Description

- Ap 0-18 cm, ---Dark brown (10 YR 3/3); clay; medium, weak, sub angular blocky structure; slightly hard, loose, very sticky, very plastic; very fine many, fine

many pores; very fine many, fine many roots; slight effervescence; moderately alkaline (pH 7.7); clear smooth boundary.

Bw₁ 18-36 cm, --- Dark brown (10 YR 3/3); clay; medium, weak, sub angular blocky structure; slightly hard, loose, very sticky, very plastic; very fine many, fine many pores; very fine many, fine many roots; violent effervescence; moderately alkaline (pH 7.9); clear smooth boundary.

Bw₂ 36-55 cm, ---Very dark grayish brown (10 YR 3/2); clay; medium, strong, sub-angular blocky structure; slightly hard, friable, very sticky, very plastic; very fine many, fine many pores; fine many, coarse few roots; violent effervescence; moderately alkaline (pH 8.1); clear smooth boundary.

Bss₁ 55-80 cm, ---Very dark greyish brown (10 YR3/2); clay; medium, strong, angular blocky structure, hard, friable; slightly sticky, slightly plastic; very fine many, fine many pores; very fine many, fine many roots; violent effervescence; moderately alkaline (pH 8.2); abrupt irregular boundary.

Bss₂ 80-100 cm, ---Very dark grayish brown (10 YR3/2); clay; medium, strong, angular blocky structure, hard, friable; non sticky, non-plastic; very fine many, fine many pores; very fine many, fine few roots; violent effervescence; moderately alkaline (pH8.2); abrupt irregular boundary.

Bss₃ 100+ cm, ---Very dark gray (10 YR 3/1); clay; medium, strong, sub-angular blocky structure; hard, firm, non-sticky, non-plastic; very fine many, fine many pores; fine few, coarse few roots; violent effervescence; moderately alkaline (pH 8.3); abrupt irregular boundary.

4.2.1 Soil depth

The soil depth is very important factor in the crop production which affects the crop yield in general, increase in soil depth will reflect in yield (Bhaskar *et al.*1987). Soil depth is a basic characteristic in land evaluation as it is partly controlling the water holding capacity, available water capacity, storage of nutrients and providing volume to the root biomass production. Soil depth data presented in Table 4.2, indicated that, soil depth was (30 cm) shallow in Calcic Haplustepts (P₁), moderately deep to very deep (90+ cm) in Calcic Haplusterts (P₂) and moderately

deep to deep (90 + cm) in Calcic Haplusterts. (P₃) The variation in soil depth might be due to the landform setting, (Vadivelu *et al.* 1983).

4.2.2 Soil colour

It is used to identify the boundaries of different horizons within a soil profile, estimation of the origin of a soil's parent material and soil classification. It is an indication of wetness and waterlogged conditions of soil. Colour is recorded in the Munsell color chart as for intensity 10YR3/4, with 10YR as hue, 3 as value and 4 as chroma. Munsell color i.e. (hue, value and chroma) the hue, value and chroma indicates that, the dominant spectral color, lightness or darkness of a color and strength of color respectively. Soil color is mostly influenced by soil mineralogy, organic matter content, drainage conditions, and degree of oxidation. Development of color in a soil profile must be due to the chemical, biological and weathering, due to the primary minerals in soil parent material, the elements combine into new and colorful compounds. The black color of soil usually indicates the presence of organic matter and titaniferous magnetite; red colors due to the presence of free iron oxides and commonly found in the humid tropical region.

The low chroma talks about poor drainage of soil sand. The dark color may be due to high dark colored ferromagnesian minerals in the soils of the study area colors in the hue 10 YR, values 3 and chroma of soil ranging from 1 to 4. The poor drainage of the soils indicates that, the low chroma of soil. The dark color of the soils was due to the presence of organic matter and high dark-colored ferromagnesian minerals.

The data presented in Table 4.2, indicates that most of soils of the study area were very dark grayish brown (10 YR 3/2) to dark brown (10 YR 3/3) in color. The pedon P₁ Calcic Haplustepts soils colour varied from very dark grayish brown (10 YR 3/2) to dark brown (10 YR 3/3) in color. The P₂ and P₃ (Calcic Haplusterts) soil colour varied from very dark grayish brown (10 YR 3/1) to very pale brown (10YR 3/4).

4.2.3 Soil structure

It gives an idea to its organic matter content, texture, biological activity, soil evolution, human use, and the chemical and mineralogical conditions

under which the soil was formed. The soil structure is the aggregation of primary soil particles into large units called as peds. It is also called as the arrangement of primary soil particles into secondary units. The secondary units are characterized and classified based on shape, classes, size and degree of distinctness into size, types and grades respectively.

The soils have structure ranged from medium, strong, angular blocky to medium, weak, sub-angular blocky in structure in P₂ and P₃ (Calcic Haplusterts) showed slightly well-developed intersecting slickenside and wedge-shaped structural aggregates (Plate- 4.3). This may be due to swell shrink properties of Vertisol's in such soils resulting in the development of slickenside's (Ahmad 1989). In P₁ Calcic Haplustepts soil's structure ranged from medium, strong, sub-angular blocky to granular soils structure.

4.2.4 Soil consistency

It is an ability of soil to stick to other objects i.e., cohesion and adhesion. It has ability to resist deformation and rupture. In the wet condition, the two qualities i.e., stickiness and plasticity are obtained. The soil is resistance to fragmentation and crumbling is assessed in dry state by rubbing the sample on hand. The resistance of shearing forces is assessed in the moist state by thumb and finger pressure.

The consistency is shown in Table 4.2, showed that in pedon P₁ (Calcic Haplustepts) the soil consistency was soft in dry condition, friable in moist condition and slightly sticky, slightly plastic to non-sticky and non-plastic in wet condition. The pedon P₂ (Calcic Haplusterts) shown soil consistency varied from soft to very hard in dry condition, friable to firm in moist condition and slightly sticky and slightly plastic. While in pedon P₃ (Calcic Haplusterts) soils consistency was varied from soft in dry condition, slightly firm to very hard in dry condition, friable in moist condition and slightly sticky, slightly plastic to very sticky and very plastic in wet condition.

4.2.5 Soil texture

The soil texture is the relative proportion of sand, silt and clay. The properties that are influenced by soil texture i.e., porosity, shrink-swell rate, permeability, infiltration, water-holding capacity. Clay soils are also resisting wind

and water erosion better than silty and sandy soils, as the particles bond tightly fixed to each other and reflected in reducing the effect of organic matter. In medium-textured soils, clay is often wash downward through the soil profile and accumulates in sub soil. Soils of study area of P₁ (Calcic Haplustepts) and P₂ (Calcic Haplusterts) was clay loam in texture while pedon P₃ (Calcic Haplusterts) was clay in texture.

4.3 Physical properties of cotton growing soils of Parbhani district.

4.3.1 Coarse fragments

The data in Table 4.3 indicated that the coarse fragments of the horizon at higher topographic position P₁ (Calcic Haplustepts) was varied from 3 to 40.41 per cent with weighted mean (12.51 per cent). The higher per cent as compare to soil at lower topographic position P₂ and P₃ (Calcic Haplusterts) and it was varied from 2.04 to 7.42 and 3.92 to 37.32 per cent respectively. It was noticed that the presence of coarse fragments decreased down the slope, and therefore, the presence of coarse fragments is related with topographic situation. The maximum coarse fragment was noticed in Cr horizon.

4.3.2 Bulk density

Bulk density is the mass of soil per unit volume, including pore spaces (Hillel, 1980). The bulk density relates to combined volume of the solids and pore spaces; it helps to us for the assessment of soil porosity and compaction. We can use as an indicator for soil aeration and root penetration. Soils are composed of solids i.e., minerals and organic matter and pores which hold air and water.

The data on bulk density of soil profile samples were collected from cotton growing soils of Parbhani district is reported in Table 4.3, showed that the bulk density of soil ranged from 1.40 to 1.79 Mg m⁻³, with weighted mean of (P₁, P₂ and P₃) were 1.48, 1.53 and 1.67 Mg m⁻³ respectively In P₁, P₂ and P₃ the bulk density was increased with the increase in depth of soil.

Prasad *et al.* (2018) reported the increase in bulk density with depth, variation in bulk density of soils in different pedons might be attributed to the variation in clay along with coarse fractions or gravels, partially decomposed rocks and intensity of plant roots or organic matter in different horizons, and compaction of

soil. The bulk density of Calcic Haplusterts increases with increased in the depth which is highly correlated with amount of clay present in the soil (Ahuja *et al.* 1988).

Table 4.3 Physical properties of cotton growing soils of Parbhani district.

Horizons	Depth (cm)	Coarse fragment (%)	BD (Mg m ⁻³)	HC (Cmhr ⁻¹)	Particle size analysis (%)			Moisture retention (%)		AWC (%)	PAWC (%)
					Sand	Silt	Clay	33kPa	1500kPa		
Pedon 1 Shri. Sangram Hange, Margalwadi Tq. Gangakhed Dist. Parbhani (Calcic Haplustept)											
Ap	0-16	3.00	1.47	7.91	8.90	44.10	47.0	37.16	27.12	10.04	53.0621
Bw ₁	16-30	3.45	1.41	6.29	12.70	38.30	49.0	38.24	28.41	9.83	
Cr	30+	40.41	1.62	14.43	43.02	26.58	30.4	22.28	16.41	5.87	
Pedon 2 Shri. Yashwant Deshmukh, Maak, Tq. Jintur Dist. Parbhani (Calcic Haplustert)											
Ap	0-22	2.14	1.41	7.71	7.20	44.2	48.60	39.12	28.11	10.89	170.2012
Bw ₁	22-32	3.40	1.40	6.22	6.91	44.09	49.00	37.33	32.27	5.06	
Bw ₂	32-50	2.04	1.52	5.21	9.28	39.00	51.72	37.04	25.23	11.81	
Bss ₁	50-90	3.73	1.60	4.38	18.31	28.80	52.89	39.20	24.94	14.26	
Bss ₂	90+	7.42	1.70	5.94	28.20	20.80	51.00	32.10	26.70	5.40	
Pedon 3 Shri. Shubham Pawar, Zodgaon Tq. Selu Dist. Parbhani (Calcic Haplustert)											
Ap	0-18	3.92	1.43	5.98	5.9	34.8	59.3	42.49	27.89	14.60	258.85
Bw ₁	18-36	4.00	1.62	5.52	4.3	34.3	61.4	36.34	24.60	11.74	
Bw ₂	36-55	4.41	1.69	5.41	6.3	30.8	62.9	36.21	24.24	11.97	
Bss ₁	55-80	5.11	1.71	5.28	7.0	29.3	63.7	38.34	25.21	13.13	
Bss ₂	80-100	4.87	1.75	4.92	4.4	30.7	64.9	34.28	23.29	10.99	
Bss ₃	100+	37.32	1.79	5.04	3.5	33.3	63.2	46.40	31.38	15.02	

The higher bulk density in murrum layer in Table 4.3 may be due to its more compactness and presence of weathered parent material. Higher bulk density of murrum layer was also reported by Patil *et al.* (2013).

4.3.3 Saturated hydraulic conductivity

The saturated hydraulic conductivity of cotton growing soils of Parbhani district varied from 4.38 to 14.43 cm hr⁻¹. These changes were due to textural difference among the pedons. The saturated hydraulic conductivity of soils of Calcic Haplustepts (P₁) was varied from 6.29 to 14.43 cm hr⁻¹; Calcic Haplustersts (P₂) and (P₃) ranged from 4.38 to 7.71 cm hr⁻¹. The weighted mean of P₁, P₂ and P₃ were 8.97, 5.68 and 5.34 cm hr⁻¹ respectively. The hydraulic conductivity of surface horizon (Ap) is higher than lower layer (B horizon) in pedon P₁, P₂. The above data shows that the hydraulic conductivity of soil decreases with increasing clay per cent. These changes may be due to addition of organic matter which enhances the porosity of soil.

Similar results were found by Patil *et al.* (2013). The hydraulic conductivity of sub-surface horizon is higher as compared to the surface horizon. This may be due to high clay content in the sub surface layer and lateral pressure. This is due to presence of loose weathered murrum layer.

4.3.4 Particle size distribution

The general of physical nature of soil gives knowledge about its chemical properties. The particle size distribution related directly or indirectly to plant growth. It also helps to understand in respect of soil water retention, nutrient retention, nutrient availability, workability, drainage condition and crop suitability. Soil particles are basically consisting of sand, silt, clay and organic matter. Sand particles size which varied from 0.05 mm to 2.0 mm. The Silt particle size ranged from 0.05 mm to 0.002 mm and clay particle size was less than 0.002 mm in size.

The cotton growing soils of Parbhani district are developed from basaltic parent material. The soil developed on basalt produces high amount of clay after weathering (Eswaran *et al.* 1988).

The data represented in Table 4.3, showed that the particle size distribution in all surface samples under study area was clay loam to clay in nature. The highest clay content was found in the pedon (P₃) 64.9 per cent. The soils of Calcic Haplustepts (P₁) clay content ranged from 30.40 to 47.00 per cent. The soils of Calcic Haplusterts (P₂) clay content varied from 48.6 to 52.89 per cent. Whereas, Calcic Haplusterts (P₃) clay content varied from 59.3 to 64.9 per cent which correspond to clay texture. The weighted mean of P₁, P₂ and P₃ were 43.55, 51.15 and 53.79 per cent respectively. The hydraulic conductivity of soil decreased with increasing clay per cent. The data state that, soil was developed on lower topographic position states higher clay content than soil developed on higher topographic position. Hence, topography and slope were found to be affecting the particle size distribution.

Moreover, the higher CEC achieved in Calcic Haplusterts 59.3 to 64.9 per cent clay and low CEC was obtained in Calcic Haplustepts 30.40 per cent clay. This it was further clear that the significant positive correlation was found between clay content of soil and CEC ($r=0.98^*$). This indicated that increased in clay content of soil increases the CEC (Fig.4.1) Similar results were found by Ghode (2021) under the tamarind growing soils of Marathwada region of Maharashtra, that the significant positive correlation was noticed between clay content of soil and CEC ($r=0.50^*$).

4.3.5 Moisture retention

The data represented in Table 4.3 states that the moisture retention mainly depends up on the amount and size of clay particles and the type of clay minerals present in the soil. The moisture retention increased with depth of the soil at 33 kPa as well as 1500 kPa. Generally, the deep soils Calcic Haplusterts (P₂, P₃) showed higher moisture retention which may be due to the increase in clay and the smectite clay minerals which are having large surface area to retain the higher amount of water at high section (Ali and Biswas, 1971).

The moisture retention in Calcic Haplustepts (P₁) soils was ranged from 22.28 to 37.16 at 33 kPa and 16.41 to 27.12 at 1500 kPa, in Calcic Haplusterts (P₂) soils between 32.10 to 39.20 at 33 kPa and 24.94 to 32.27 at 1500 kPa and in Calcic Haplusterts (P₃) soils ranged from 34.28 to 46.40 at 33 kPa and 23.29 to 31.38 at 1500 kPa suction respectively.

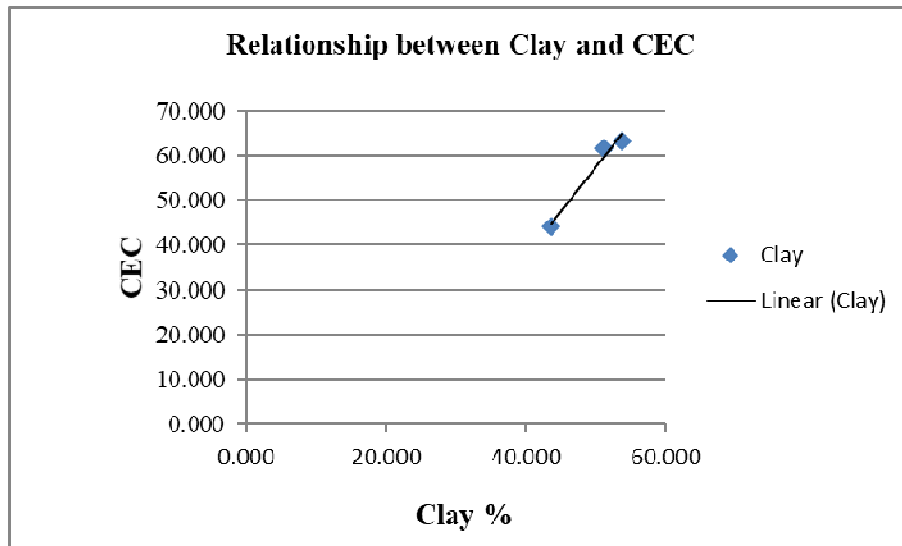


Fig .4.1 Relationship between Clay and CEC

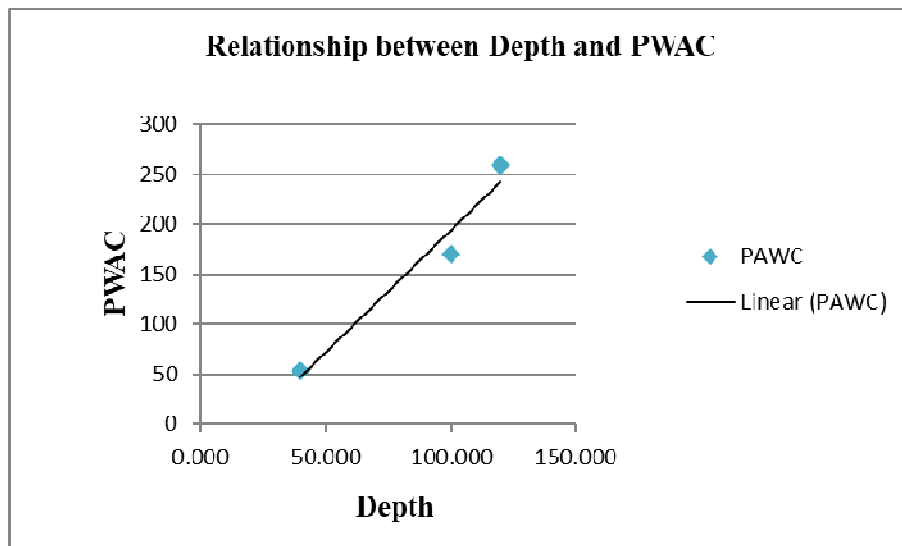


Fig .4.2 Relationship between Depth and PWAC

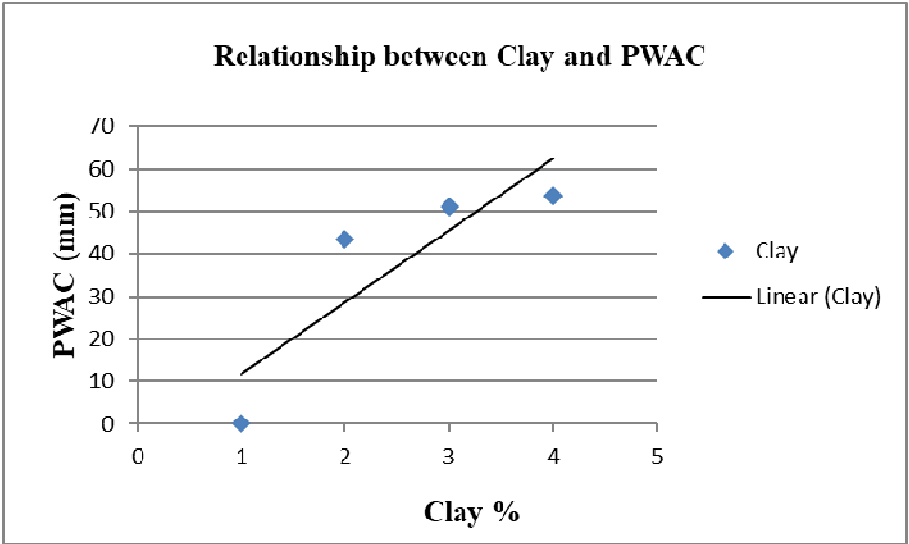


Fig .4.3 Relationship between Clay and PWAC

4.3.6 Plant available water capacity

The data revealed in Table 4.3 showed that the available water capacity of the soils of Calcic Haplustepts (P_1) ranged from 5.87 to 10.04 per cent and PAWC value was 53.06 mm. The soils of Calcic Haplusterts (P_2) have AWC value ranged from 5.06 to 14.26 per cent and PAWC value i.e., 170.20 mm. The available water capacity of soils of Calcic Haplusterts (P_3) ranged from 10.99 to 15.02 per cent and PAWC value is 258.85 mm. These observations showed that the maximum plant available water content in soils of Calcic Haplusterts followed by Calcic Haplustepts.

However, murrum layer observed low PAWC than to their respective soil. The PAWC was found to increased with depth in soil. Gardner *et al.* (1984) reported that the plant available water capacity is limited by rooting depth. The capacity of soil to store moisture for plant and use is largely relating a function to their clay content, depth of soil and mineralogy of soil.

The correlation of soil depth with PAWC ($r = 0.97^*$) and clay content with PAWC ($r=0.98^*$) were found significantly positive correlation (Fig. 4.2 and 4.3). It was noted that, the soil depth, texture and PAWC are interrelated to each other and control the yield of crop. This indicates that, the PAWC increases with the increased in soil depth. Similar results were recorded by Aundhkar (2018) that the correlation between soil depth and PAWC ($r=0.83^{**}$) and clay content and PAWC ($r=0.74^*$) significantly positive obtained.

4.4 Chemical properties of cotton growing soils of Parbhani District.

4.4.1 Soil reaction

It is a very important parameter of soil because it affects the availability of essential nutrients to plant growth. The Soil pH measured the acidity or basicity of the soil. It specifically influenced on plant nutrient availability by controlling the chemical forms of the different nutrients and affecting the chemical reactions they go through.

The data given in Table 4.4 stated that, the pH of soils was varied from 7.5 to 8.4. The lowest pH value was observed in Ap horizon (P_1) at 0 to 16 cm while, the highest pH value was observed in Bss₂ horizon (P_2) at 90+ cm depth. Bss₂ horizon

(P₂) at 50 to 90 cm depth, Bss₂ horizon (P₃) at 80 to 100 cm depth and Bss₃ horizon (P₃) at 100+ cm depth. The pH in Calcic Haplustepts (P₁), Calcic Haplusterts (P₂) and Calcic Haplusterts (P₃) ranged from 7.5 to 7.8, 7.7 to 8.4 and 7.7 to 8.3 respectively. The weighted mean of P₁, P₂ and P₃ were 7.61, 7.97 and 8.08 pH respectively. Sayambar (2015) observed that the soils of Tungi watershed in Latur district of Maharashtra were slightly to strongly alkaline in reaction. The soil pH increases with increasing depth of soil and this may be due to leaching of bases. The pH data indicated that the soils were slightly to moderately alkaline in reaction.

4.4.2 Electrical conductivity

Electrical conductivity states the total soluble salts present in the soil solution. In case of profile soil samples, the data indicated that, the salt concentration in the soil ranged from 0.16 to 0.32 dSm⁻¹. The lowest EC value was observed in B_{w1} horizon (P₂) at 22 to 32 cm depth and the highest EC value was observed in Bss₁ horizon (P₂) at 50 to 90 cm depth. The weighted mean of P₁, P₂ and P₃ were 0.16, 0.20 and 0.22 dsm⁻¹ respectively.

The EC value of murrum layer as relatively less than surface layer (0.1 to 0.2 dSm¹) which was within safe limit of electrical conductivity range, designated for normal soil (Richards,1954) and all soils comes under non-saline class. It was found that EC values increased with increase in depth of soil. This may be due to leaching of soluble salts from surface horizon to sub surface horizon. The soil were found in safe limit of electrical conductivity and were categorized as safe in salt concentration and electrical conductivity of soils increased with increase in soil depth. Irregular changes in EC due to the leaching of salt from surface to down ward into soil by percolation of water. Similar results were found by Patil *et.al* (2013), Shinde (2015), Vaidya *et al.* (2014) that the electrical conductivity of soils increased with increase in soil depth.

4.4.3 Organic carbon

Soil organic carbon plays an important role in chemical composition and biological productivity and play role on fertility and nutrient holding capacity of a soil. An increase in soil organic carbon typically results in a more stable carbon cycle and improve overall agricultural productivity. The organic carbon content of soil

profile samples varied from 0.1 to 0.5 per cent. The lowest organic carbon content was found in Cr horizon (P₁) at 30+ cm depth. While the highest organic carbon content was recorded in Ap horizon (P₃) at 0-18 cm depth. In (P₁) Calcic Haplustepts and soil organic carbon was ranged from 0.1 to 0.5 percent, in soil ranged from 0.1 to 0.5 percent and Calcic Haplusterts (P₃) was found between 0.1 to 0.5 per cent. The weighted mean of P₁, P₂ and P₃ were 0.33, 0.31 and 0.28 per cent of organic carbon respectively. Soil samples were noted in the low category in organic carbon content. It was found that as a depth increases the organic carbon percent decreased. In surface soil has high organic carbon due to addition of organic matter.

The maximum organic carbon content was noticed in surface soil may be due to the more addition of roots and plant biomass in surface layer. The organic carbon was low in murrum layer than the over lying horizon. Similar, results were given by Ghode *et al.* (2018), the organic carbon content decreased with increase in depth of soil of cotton growing soils of Nanded district.

4.4.4 Calcium carbonate

Calcium carbonate is one of the cementing agent which participate in the binding of soil particles together through physio-chemical mechanisms and create a stable soil structure.

The data represented in Table 4.4, indicated that the calcium carbonate content in soil profile samples of Calcic Haplustepts (P₁) was ranged from 7.8 to 21.9 per cent, in Calcic Haplusterts (P₂) ranged from 8.6 to 28.4 per cent and Calcic Haplusterts (P₃) ranged from 8.3 to 20.6 per cent. The weighted mean of P₁, P₂ and P₃ were 12.41, 13.20 and 14.43 per cent respectively. These soils are calcareous in nature.

The high calcium carbonate content in soil influence the available water capacity of soil, which had a great effect on crop production under rainfed conditions. Similar results were found by Mane *et al.* (2015) revealed that, the grape growing soils of Osmanabad district having calcium carbonate between 10 to 29.4 per cent, indicating the soils were calcareous in nature.

In present investigation, it was noted that, the calcium carbonate increased with increasing depth of soils. Higher amount of calcium carbonate at

lower depths may be due to the leaching process of calcium carbonate and subsequent precipitation at lower depth.

The similar results were reported by Aundhkar *et al.* (2018) the calcium carbonate increased with increasing depth of soils of cotton growing soils of Beed district.

Table 4.4: Chemical properties of cotton growing soils of Parbhani District.

Horizons	Depth	pH	EC	OC	CaCO ₃	CEC (cmol(P ⁺) kg ⁻¹)	Exchangeable Cations (cmol (P ⁺) kg ⁻¹)				Sum of Cations	Base saturation (%)
							Ca ⁺⁺	Mg ⁺⁺	Na ⁺	K ⁺		
Pedon 1 Shri. Sangram Hange Margalwadi, Gangakhed, Parbhani (Calcic Haplustept)												
Ap	0-16	7.5	0.18	0.5	7.8	49.21	32.20	13.6	0.62	0.79	47.21	95.93
Bw ₁	16-30	7.6	0.21	0.3	10.9	43.14	29.80	11.5	0.39	0.82	42.51	98.53
Cr	30+	7.8	0.22	0.1	21.9	37.20	21.09	12.8	0.31	1.12	35.32	94.94
Pedon 2 Shri. Yashwant Deshmukh Maak, Jintur, Parbhani (Calcic Haplustert)												
Ap	0-22	7.8	0.17	0.5	8.6	62.18	40.43	19.5	0.36	0.73	61.02	98.13
Bw ₁	22-32	7.7	0.16	0.5	8.8	53.57	38.06	13.2	0.31	0.53	51.57	96.26
Bw ₂	32-50	7.8	0.23	0.3	12.6	59.49	37.19	18.3	0.27	0.83	57.47	96.60
Bss ₁	50-90	8.1	0.32	0.2	13.3	63.24	41.27	19.2	0.24	1.22	62.03	98.08
Bss ₂	90+	8.4	0.28	0.1	28.4	66.18	42.10	20.8	0.21	1.95	65.06	98.30
Pedon 3 Shri. Shubham Pawar, Zodgaon, Selu, Parbhani (Calcic Haplustert)												
Ap	0-18	7.7	0.19	0.5	8.3	61.03	32.04	23.70	0.85	1.34	59.93	98.19
Bw ₁	18-36	7.9	0.24	0.5	9.5	62.89	31.00	22.80	0.76	1.42	55.98	96.70
Bw ₂	36-55	8.1	0.26	0.3	12.4	62.93	33.08	21.01	0.40	1.93	56.03	96.82
Bss ₁	55-80	8.2	0.23	0.2	16.9	62.87	36.20	23.08	0.41	1.87	61.38	98.39
Bss ₂	80-100	8.2	0.30	0.2	17.1	63.88	36.04	22.09	0.42	1.91	60.46	97.77
Bss ₃	100+	8.3	0.31	0.1	20.6	65.64	38.02	21.30	0.38	1.96	61.66	98.43

4.4.5 Cation exchange capacity

The data presented in Table 4.4 indicated that the cation exchange capacity of Calcic Haplustepts (P_1) varied from 37.20 to 49.21 $\text{cmol (p}^+) \text{ kg}^{-1}$, Calcic Haplusterts (P_2) ranged from 53.57 to 66.18 $\text{cmol (p}^+) \text{ kg}^{-1}$ and Calcic Haplusterts (P_3) varied from 61.03 to 65.64 $\text{cmol (p}^+) \text{ kg}^{-1}$. The highest CEC was found in Calcic Haplusterts (P_3) than Calcic Haplusterts (P_2) and Calcic Haplusterts (P_1). The weighted mean of P_1 , P_2 and P_3 were 44.08, 61.64 and 63.23 $\text{cmol (p}^+) \text{ kg}^{-1}$ of CEC respectively. The high CEC was observed due to the high amount of clay. Clay fraction appears largely which affects the cation exchange capacity values. The change in behavior of soils due to cation exchange capacity of soils, whereas, the clay is the fundamental block contributing towards its cation exchanges.

Clay particles appears to influence largely on cation exchange capacity values. The higher cation exchange capacity of black soils was due to its smectite clay mineral present in black soil. (Pal and Deshpande, 1987).

The relationship of cation exchange capacity and clay content in soil found to be significant positive correlation ($r=0.98^*$) and which was increased with increasing clay content in soil (Fig. 4.2). Similar results were obtained by Adkine (2016) the relationship of cation exchange capacity and clay content was significant positively correlated ($r=0.93$) and which was increased with increasing clay content, Similar results were found by Pawar *et al.* (2014) and observed that the relationship between cation exchange capacity and clay content in soil was found significantly positive ($r=0.93$).

4.4.6 Exchangeable bases

The exchangeable bases in Table 4.4, showed that the dominance of exchangeable calcium followed by exchangeable magnesium, exchangeable sodium and exchangeable potassium in all profiles. Calcic Haplustepts (P_1) have calcium content varied from 21.09 to 32.2 $\text{cmol (p}^+) \text{ kg}^{-1}$, magnesium varied from 11.5 to 13.6 $\text{cmol (p}^+) \text{ kg}^{-1}$ while sodium content ranged between 0.79 to 1.12 $\text{cmol (p}^+) \text{ kg}^{-1}$ and potassium content varied from 0.31 to 0.62 $\text{cmol (p}^+) \text{ kg}^{-1}$. In soils of Calcic Haplusterts (P_2) exchangeable calcium ranged from 37.19 to 42.10 $\text{cmol (p}^+) \text{ kg}^{-1}$, magnesium 20.8 to 13.2 $\text{cmol (p}^+) \text{ kg}^{-1}$, sodium 0.53 to 1.95 $\text{cmol (p}^+) \text{ kg}^{-1}$ and

potassium content ranged from 0.21 to 0.36 cmol (p⁺) kg⁻¹ respectively. In soils of Calcic Haplusterts (P₃) exchangeable calcium, magnesium, sodium and potassium varied from 31 to 38.02 cmol (p⁺) kg⁻¹, 21.01 to 23.08 cmol(p⁺) kg⁻¹, 1.34 to 1.96 cmol (p⁺) kg⁻¹ and 0.38 to 0.85 cmol (p⁺) kg⁻¹ respectively. Generally, these soils are saturated with bases specially calcium and magnesium where calcium is dominant cation and other cations showed the presence of calcium bearing mineral.

4.4.7 Base saturation

The data showed that the narrow changes in the per cent base saturation among themselves. Base saturation ranged from 94.94 to 98.43 per cent. The weighted mean of P₁, P₂ and P₃ were 96.59, 97.66 and 97.76 per cent of base saturation respectively. The higher base saturation of soils was attributed to basaltic parent material and presence of free lime.

4.5. Fertility status of soil

The data in respect of macronutrient status i.e., nitrogen, phosphorus, potassium and sulphur of cotton growing soils of Parbhani district described as under.

4.5.1 Available macronutrients.

4.5.1.1 Available nitrogen

The data revealed in Table 4.5, showed that the available nitrogen content in cotton growing soils of Parbhani district varied from 81.5 to 245 kg ha⁻¹. These soils were observed as very low to low in available nitrogen content of surface Ap horizon. The higher amount of nitrogen content (weighted mean) was found in Calcic Haplustepts (P₁) 159.27 kg ha⁻¹ followed by Calcic Haplusterts (P₂) 148.62 kg ha⁻¹ and lower amount in Calcic Haplusterts (P₃) 136.37 kg ha⁻¹. The maximum available nitrogen content found in AP horizon. The presence of nitrogen in Cr horizon is low than surface layer. These may be caused due to the leaching of top soil nitrogen to the sub-surface. The available nitrogen content of soils was decreased with increasing depth of soil.

Similar results were reported by Ghode *et al.* (2018). The available nitrogen content decreased with increase in depth of soil of cotton growing soils of Nanded district. This may due to addition of organic matter and plant residues.

4.5.1.2 Available phosphorus

The data on available phosphorus present in soil profile recorded in Table 4.5 the data showed that the available phosphorus in this soil was ranged from 7.2 to 23.4 kg ha⁻¹. The lowest available phosphorus was found in Bss₃ (P₃) horizon at 100+ cm depth. However, the highest available phosphorus content was observed in Ap horizon (P₂) at 0 to 22 cm depth. The higher amount of available phosphorus content (weighted mean) was observed in Calcic Haplustepts (P₁) 18.07 kg ha⁻¹ followed by Calcic Haplusterts (P₂) 15.54 kg ha⁻¹ and lower was noticed in Calcic Haplusterts (P₃) 13.86 kg ha⁻¹. The data showed that the available phosphorus present in soils of Parbhani district was found to be decreased with increasing depth of soil. The surface layer of soils contains higher amount of phosphorus than sub-surface layer of soil, these may due to phosphorus providing fertilizers.

In the present investigation it was seen that the available phosphorus content decreased with increasing depth and similar results were found by Vaidya *et al.* (2014). phosphorus content was low to moderate in surface soil sample whereas, Phosphorus content was very low to moderate in profile soil samples.

The available phosphorus showed decreasing trend with an increase in depth of the soil. The simillar results were found by Ghode (2017), reported that the available phosphorus in soils of Nanded district showed decreasing trend with an increase in depth of the soil.

Table 4.5: Available macronutrients in cotton growing soils of Parbhani District.

Horizons	Depth (cm)	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O (kg ha ⁻¹)	S (mg kg ⁻¹)
Pedon 1 Shri.Sangram Hange, Margalwadi, Gangakhed, Parbhani (Calcic Haplustept)					
Ap	0-16	235.0	21.33	381.0	13.96
Bw ₁	16-30	118.2	18.74	259.3	12.14
Cr	30+	95.6	11.93	103.0	9.98
Pedon 2 Shri. Yashwant Deshmukh, Maak,Jintur,Parbhani(Calcic Haplustert)					
Ap	0-22	245.5	23.40	408.0	12.18
Bw ₁	22-32	197.2	21.14	316.0	10.28
Bw ₂	32-50	134.8	17.33	268.0	11.88
Bss ₁	50-90	106.2	12.91	301.1	11.38
Bss ₂	90+	81.5	9.70	297.6	9.33
Pedon 3 Shri. Shubham Pawar, Zodgaon, Selu,Parbhani(Calcic Haplustert)					
Ap	0-18	239.3	19.66	694.4	13.63
Bw ₁	18-36	153.3	22.46	459.2	12.74
Bw ₂	36-55	123.4	11.37	366.0	10.33
Bss ₁	55-80	125.2	13.58	358.0	8.98
Bss ₂	80-100	107.9	10.33	302.0	9.53
Bss ₃	100+	83.3	7.20	324.8	7.94

4.5.1.3 Available potassium

The data revealed in Table 4.5 showed that the available potassium content of these soils varied from 103 to 694 kg ha⁻¹. The lowest available potassium content was observed in Cr horizon (P₁) at 30+ cm depth. However, the highest available potassium content was observed in Ap horizon (P₃) 694.4 kg ha⁻¹ at 0-18 cm depth. The highest weighted mean was found in Calcic Haplustepts (P₁) 268.90 kg ha⁻¹ followed by Calcic Haplusterts (P₂) 319.80 kg ha⁻¹ and Calcic Haplusterts (P₃) 410 kg ha⁻¹. The Calcic Haplustepts (P₁) showed that the available potassium content varied from 103 to 259.3 kg ha⁻¹, in Calcic Haplusterts (P₂) contain available potassium between 268 to 408 kg ha⁻¹ while, Calcic Haplusterts (P₃) shows that the available potassium content varied from 302 to 694.4 kg ha⁻¹. The soil samples were collected from study area indicated that the available potassium in soils were very high and it is decreased with increasing depth.

The similar results were obtained by Ghode *et al.* (2018) and reported

that the available potassium in soils of Nanded district is high and showed trend decreasing with an increase in depth of soil.

4.5.1.4 Available sulphur

The data on available sulphur in the soils of study area indicated that the lowest available sulphur values was observed in Bss₃ horizon (P₃) at 100+ cm depth and highest available sulphur was observed in AP horizon (P₁) at 0 to 16 cm depth. The weighted mean was found in Calcic Haplustepts (P₁) 12.32 mg kg⁻¹ followed by Calcic Haplusterts (P₂) 11.33 mg kg⁻¹ and Calcic Haplusterts (P₃) 10.37 mg kg⁻¹. The available sulphur in Calcic Haplustepts (P₁) varied from 9.98 to 13.96 mg kg⁻¹, Calcic Haplusterts (P₂), available sulphur varied from 9.33 to 12.18 mg kg⁻¹, Calcic Haplusterts (P₃) available sulphur between 7.94 to 13.63 mg kg⁻¹. This indicated that soils were deficient to sufficient in available sulphur in these soils. The available sulphur content of these soils was decreased with increasing depth in soil.

Surface layer of soil contain higher amount of sulphur than sub-surface layer of soil, these may due to fertilizer application. Similar results were found by Ravte (2008) analyzed the soils of AUSA and Nilanga tahsils of Latur district and reported that the available S content in these soils ranged from 3.62 to 84.61 mg kg⁻¹.

4.5.2 Available micronutrients in cotton growing soils of Parbhani District.

Cotton requires both major and micronutrients for proper growth and development. Out of many micronutrients, the available four nutrients are important i.e., Fe, Mn, Cu and Zn which are found to be affected the growth and yield of the crop though iron is not a constituent of chlorophyll, it is essential for its synthesis. It acts as catalyst in enzyme action in plant metabolism. Manganese is essential for chlorophyll synthesis. Copper is constituent of several enzymes' participation in the cellular oxidation-reduction processes while, zinc is taking part in the biosynthesis of a plant hormone. It also plays role nucleic acid, protein and chlorophyll synthesis.

The micronutrient content in soils of Parbhani district regarding Fe, Mn, Zn and Cu varied from 2.70 to 6.04, 1.16 to 4.80, 0.10 to 0.78 and 1.42 to 4.82 mg kg⁻¹ respectively. The table 4.6 indicated that the soils are high in Fe followed by Mn, Cu, and Zn. The higher amount of Fe and Mn content in these soils may be due to the ferromagnesian parent material available in this soil. The available

micronutrient content in surface layer was found to be more than sub surface layers. This may be due to surface application of micronutrient fertilizers. Generally, trend is that the decreasing availability of micronutrients with an increase in depth of the soil.

Table 4.6: Available micronutrients in cotton growing soils of Parbhani District.

Horizons	Depth (cm)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)	Cu (mg kg ⁻¹)
Pedon 1 Shri.Sangram Hange, Margalwadi,Gangakhed .Parbhani (Calcic Haplustepts)					
Ap	0-16	6.04	4.74	0.58	3.04
Bw ₁	16-30	4.24	3.02	0.46	3.79
Cr	30+	5.00	2.50	0.28	2.57
Pedon 2 Shri. Yashwant Deshmukh, maak,Jintur Parbhani (Calcic Haplusterts)					
Ap	0-22	4.12	2.00	0.25	3.93
Bw ₁	22-32	4.64	4.82	0.32	4.82
Bw ₂	32-50	4.20	3.88	0.18	2.76
Bss ₁	50-90	4.08	1.82	0.44	1.94
Bss ₂	90+	3.20	1.16	0.14	1.42
Pedon 3 Shri. Shubham Pawar, Zodgaon, Selu Parbhani (Calcic Haplusterts)					
Ap	0-18	5.40	3.48	0.28	2.90
Bw ₁	18-36	5.26	2.52	0.23	2.58
Bw ₂	36-55	4.64	3.18	0.24	2.89
Bss ₁	55-80	5.34	2.22	0.26	2.82
Bss ₂	80-100	4.00	2.58	0.19	2.30
Bss ₃	100+	2.70	2.51	0.22	1.62

4.5.2.1 DTPA Extractable Iron

The data revealed in Table 4.6 showed that the DTPA extractable iron content in the soils of study area was ranged between 2.70 to 6.04 mg kg⁻¹ with mean value of 4.37 mg kg⁻¹. The lowest DTPA extractable iron content was observed in Bss₃ horizon at (P₃) 100+ cm depth. However, the highest DTPA extractable iron content was observed in Ap horizon (P₁) at 0 to 16 cm depth. The weighted mean was found in Calcic Haplustepts (P₁) 5.06 mg kg⁻¹ followed by Calcic Haplusterts (P₂) and (P₃) 4.13 to 4.6 mg kg⁻¹. In Calcic Haplustepts (P₁) available Fe varied from 5 to 6.04 mg kg⁻¹, Calcic Haplusterts (P₂) available Fe varied from 3.20 to 4.64 mg kg⁻¹, Calcic Haplusterts (P₃) available Fe between 2.7 to 5.40 mg kg⁻¹. It was noticed that the soil samples contained high amount of DTPA extractable iron. It was noted that available

iron content decreased with increasing depth. It might be due to micronutrient fertilizers application at surface and ferromagnesian minerals content in these soils.

Malewar *et al.*, (1998) reported that DTPA-Fe was in the range of 0.82 to 9.36 mg kg⁻¹ in surface soils of Northern Maharashtra. Similar results were also reported by Cheke, (2012).

4.5.2.2 DTPA Extractable Manganese

Data presented in Table.4.6 showed that the DTPA extractable Mn content of profile soil sample ranged from 1.16 to 4.82 mg kg⁻¹ with mean value of 2.8 mg kg⁻¹. The lowest DTPA extractable Mn content was found in Bss₂ horizon (pedon-2) at 90+ cm depth. However, the highest DTPA extractable Mn content was observed in Bw₁ (P₂) at 0-16 cm. depth. The weighted mean was found in Calcic Haplustepts (P₁) 3.57 mg kg⁻¹ followed by Calcic Haplusterts (P₂) 2.46 mg kg⁻¹ and Calcic Haplusterts (P₃) 2.71 mg kg⁻¹. In Calcic Haplustepts (P₁) available Mn varied from 2.50 to 4.74 mg kg⁻¹, Calcic Haplusterts (P₂) available Mn varied from 1.16 to 4.82 mg kg⁻¹, Calcic Haplusterts (P₃) available Mn ranged between 2.50 to 3.48 mg kg⁻¹. It was noted that extractable Mn content of study area was in higher range.

Similar results were found by Mandavgade *et al.* (2015) reported that the relative higher content of DTPA-Mn in the soils might be due to the soils derived from basaltic parent material which contained higher ferromagnesium minerals.

4.5.2.3 DTPA Extractable Zinc

The data revealed in Table 4.6 showed that the DTPA extractable Zn content in these soils ranged between 0.14 to 0.58 mg kg⁻¹ with mean value of 0.37 mg kg⁻¹. The lowest DTPA extractable Zn content was found in Bss₂ horizon (pedon-3) at 80-100 cm depth. However, the highest DTPA extractable Zn content was observed in AP horizon at (pedon-1) at 0-16 cm depth. The weighted mean was found in Calcic Haplustepts (P₁) 0.57 mg kg⁻¹ followed by Calcic Haplusterts (P₂) 0.30 mg kg⁻¹ and Calcic Haplusterts (P₃) 0.21 mg kg⁻¹. In Calcic Haplustepts (P₁) available Zn varied from 0.16 to 0.78 mg kg⁻¹, Calcic Haplusterts (P₂) available Zn varied from 0.14 to 0.44 mg kg⁻¹, Calcic Haplusterts (P₃) available Zn between 0.10 to 0.28 mg kg⁻¹. The DTPA extractable zinc content of cotton growing soils of Parbhani District

was low. It could be caused due to high clay content and calcareous nature of soils and Maharashtra soils were deficient in zinc.

Similar results were found by Malewar and Randhawa (1978) and reported that DTPA extractable Zn was ranged from 0.28 to 4.40 mg kg⁻¹ in soils of Marathwada.

4.5.2.4 DTPA Extractable Copper

Data revealed in Table 4.6, showed that the DTPA extractable copper content in soil samples, ranged from 1.42 to 4.82 mg kg⁻¹ with mean value of 2.54 mg kg⁻¹. The lowest DTPA extractable Cu content was found in Bss₂ horizon (P₂) at 90+ cm depth. However, the highest DTPA extractable Cu content was found in Bw₁ horizon (P₂) at 22 to 32 cm. depth. The weighted mean was found in Calcic Haplustepts (P₁) 3.18 mg kg⁻¹ followed by Calcic Haplusterts (P₂) 2.76 mg kg⁻¹ and Calcic Haplusterts (P₃) 2.52 mg kg⁻¹. In Calcic Haplustepts (P₁) available Cu varied from 2.57 to 3.79 mg kg⁻¹, Calcic Haplusterts (P₂) available Cu varied from 1.42 to 4.82 mg kg⁻¹, Calcic Haplusterts (P₃) available Cu between 1.62 to 2.90 mg kg⁻¹. The available copper content of cotton growing soils of Parbhani was higher as far as the critical level of Cu is concerned. It might be due to presence of chalcocite. Indulkar *et al* (2007) reported that the DTPA-Cu content in soils of Udgir and Deoni tahsil of Latur district in the range of 0.98 to 7.66 mg kg⁻¹ and 0.74 to 9.42 mg kg⁻¹, respectively.

4.6 Soil classification

On the basis of field morphology and laboratory analysis the various characteristics of soils on different landforms have been classified according to U.S. Comprehensive Soil Classification System (Soil Survey Staff 1975 & 2006) reported in Table 4.7. The major soils of the study area found under the two soil orders viz. Inceptisols and Vertisols.

Inceptisols

The pedon P₁ possess ochric epipedon followed by cambic sub-surface diagnostic horizon and hence, grouped under Inceptisols. Because of ustic moisture regime, this pedon qualify for ustepts suborder. This pedons do not have duripan

horizon and hence are classified under Haplustepts great group. At subgroup level, these soils had more than 15% calcium carbonate within 150 cm soil depth of mineral soil and it is classified as calcic Haplustepts.

Vertisols

The soils were deep to very deep, black coloured, this may be due titaniferous magnetite mineral as parent material, clayey (contains more 40 % clay) and characteristics of swelling (wet condition) and shrinkage (dry condition), well developed slickenside and pressure face. Thus, these soils, pedon P₂, P₃, were classified under the order Vertisol and at sub group level pedon P₂, P₃, were Calcic Haplusterts because this soil has contained more than 15 % calcium carbonate within 150 cm depth of mineral soil.

Table 4.7: Soil classification of cotton growing soils of Parbhani district.

Sr. No.	Order	Sub Order	Great group	Sub group	Family
1.	Inceptisols	Ustepts	Haplustepts	Calcic Haplustepts	Clay loam, montmorillonite, hyperthermic
2.	Vertisols	Usterts	Haplusterts	Calcic Haplusterts	Clay, montmorillonite, hyperthermic
3.	Vertisols	Usterts	Haplusterts	Calcic Haplusterts	Clay, montmorillonite, hyperthermic

4.7 Fertility status of soil (surface)

In order to determine physico-chemical characteristics and fertility status of available nutrients of cotton growing soils of Parbhani district are reported in Table 4.8. Forty-five representative (0-30 cm depth) soil samples were collected from different locations of adjoining area of soil profile in study area.

4.7.1 Physico-chemical properties soil

Table 4.8: Physico-chemical characteristics of cotton growing soils of Parbhani district.

Sample No.	pH	EC	O.C (%)	CaCO ₃ (%)
1	7.64	0.24	0.49	12.25
2	7.94	0.37	0.44	13.75
3	7.77	0.21	0.30	12.00
4	8.15	0.39	0.30	14.50
5	7.62	0.38	0.45	5.09
6	7.88	0.39	0.39	8.80
7	7.54	0.30	0.42	6.00
8	7.30	0.29	0.32	6.25
9	7.56	0.20	0.42	6.50
10	7.75	0.39	0.47	11.75
11	7.60	0.38	0.43	11.00
12	7.54	0.42	0.28	11.50
13	7.30	0.46	0.47	12.25
14	7.68	0.21	0.58	8.50
15	7.88	0.38	0.21	8.97
16	7.72	0.33	0.54	14.00
17	7.58	0.36	0.39	8.60
18	7.73	0.34	0.27	10.25
19	7.71	0.31	0.42	9.25
20	7.80	0.32	0.56	10.00
21	8.17	0.40	0.45	13.75
22	7.82	0.40	0.43	8.75
23	8.29	0.54	0.36	13.95
24	7.66	0.61	0.33	8.50
25	8.54	0.55	0.49	14.02
26	7.90	0.47	0.52	9.50
27	7.57	0.56	0.51	6.50
28	7.70	0.62	0.30	9.75
29	7.62	0.68	0.39	9.50
30	7.40	0.63	0.34	9.00
31	7.81	0.61	0.33	13.00
32	7.63	0.42	0.54	9.70
33	7.88	0.39	0.49	12.75
34	7.62	0.31	0.48	9.00
35	7.74	0.46	0.53	9.05
36	7.32	0.26	0.38	9.75
37	7.44	0.51	0.46	6.75
38	7.32	0.31	0.28	7.75
39	7.90	0.41	0.39	10.58
40	8.14	0.52	0.48	12.50
41	7.68	0.43	0.48	6.70
42	7.62	0.52	0.52	8.03
43	7.76	0.58	0.49	5.90
44	7.63	0.42	0.55	7.04
45	7.48	0.22	0.39	7.80
Mean	7.7245	0.41	0.42	9.79

4.7.1.1 Soil reaction

Soil pH is considered as master variable in soils, as it influences many soils chemical processes or properties. The soil pH influences the nutrient availability by changing the form of the nutrient status present in soil. The plants normally grow best at above 6.5 pH. The 6.5 pH is generally considered as optimum for nutrient availability and growth of plants. The lower pH causes and increases the solubility or availability of Al, Mn, and Fe, which act as toxic to plants, if they are present in excess amount in soil and also affects on microbial degradation, synthesis of organic acids.

The total 45 surface soil samples were collected from study area and out of that 38 (84.44 %) soil samples were under alkaline and 7 (15.55 %) samples were under the neutral range of categorization of pH (Fig. 4.4). The pH data indicated that, the soils were slightly to moderately alkaline in reaction and varied from 7.30 to 8.54.

Lowest pH value was observed in 8 number sample. This may due to the continuous application of acid producing nitrogenous fertilizers and application of farm yard manure which released some organic acids.

Similar results were observed by Chavan (2020) and noticed that soils of Basmat tehsil were slightly to moderately alkaline in nature and also, Kshirsagar (2020) reported that the soils under vegetable research scheme V.N.M.K.V Parbhani were slightly to moderately alkaline in reaction. Sunewad (2014) studied on fertility Status soils were of Central tehsils of Parbhani District (Manwat, Parbhani and Purna) and noticed that soils were moderately alkaline in soil reaction.

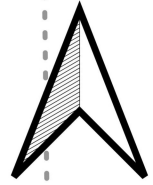
4.7.1.2 Electrical conductivity

Electrical conductivity stated that total soluble salts present in soil solution and data indicated in Table 4.8 showed that the salt concentration in surface soils samples varied from 0.20 to 0.68 dSm⁻¹ with mean value of 0.41 dSm⁻¹. The total 45 surface samples were collected from study area and out of that, all soils come under non-saline class. The soil was obtained in safe limit of electrical conductivity and categorized in safe limit of salt concentration. (Fig.4.5)

76°30'0.0"E

77°0'0.0"E

Soil pH



19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N

Legend:-

★ Soil sample

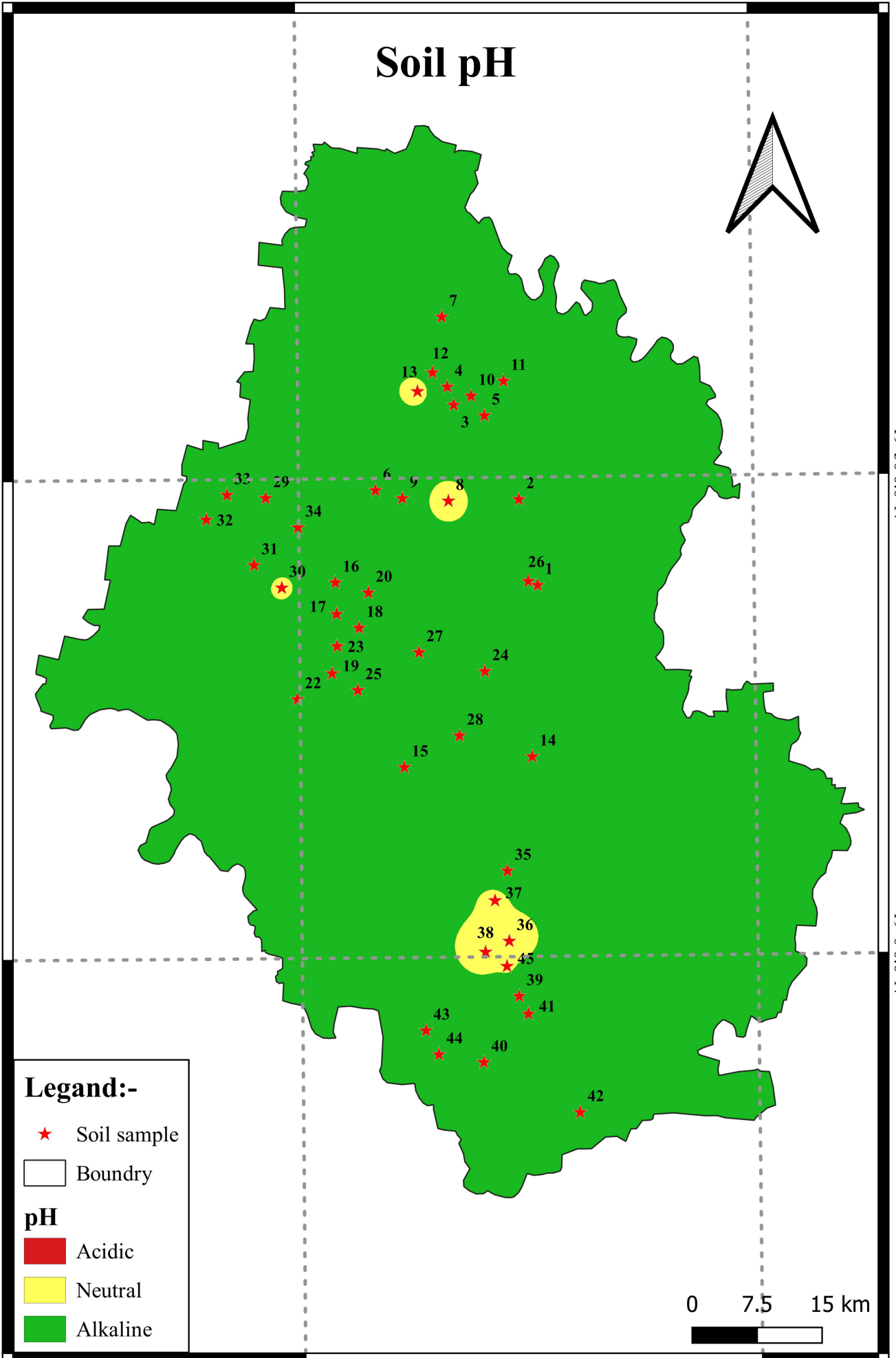
□ Boundry

pH

■ Acidic

■ Neutral

■ Alkaline



0 7.5 15 km



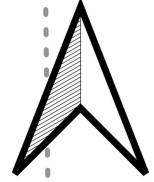
76°30'0.0"E

77°0'0.0"E

76°30'0.0"E

77°0'0.0"E

Electrical Conductivity



19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N

Legend:-

★ Soil sample

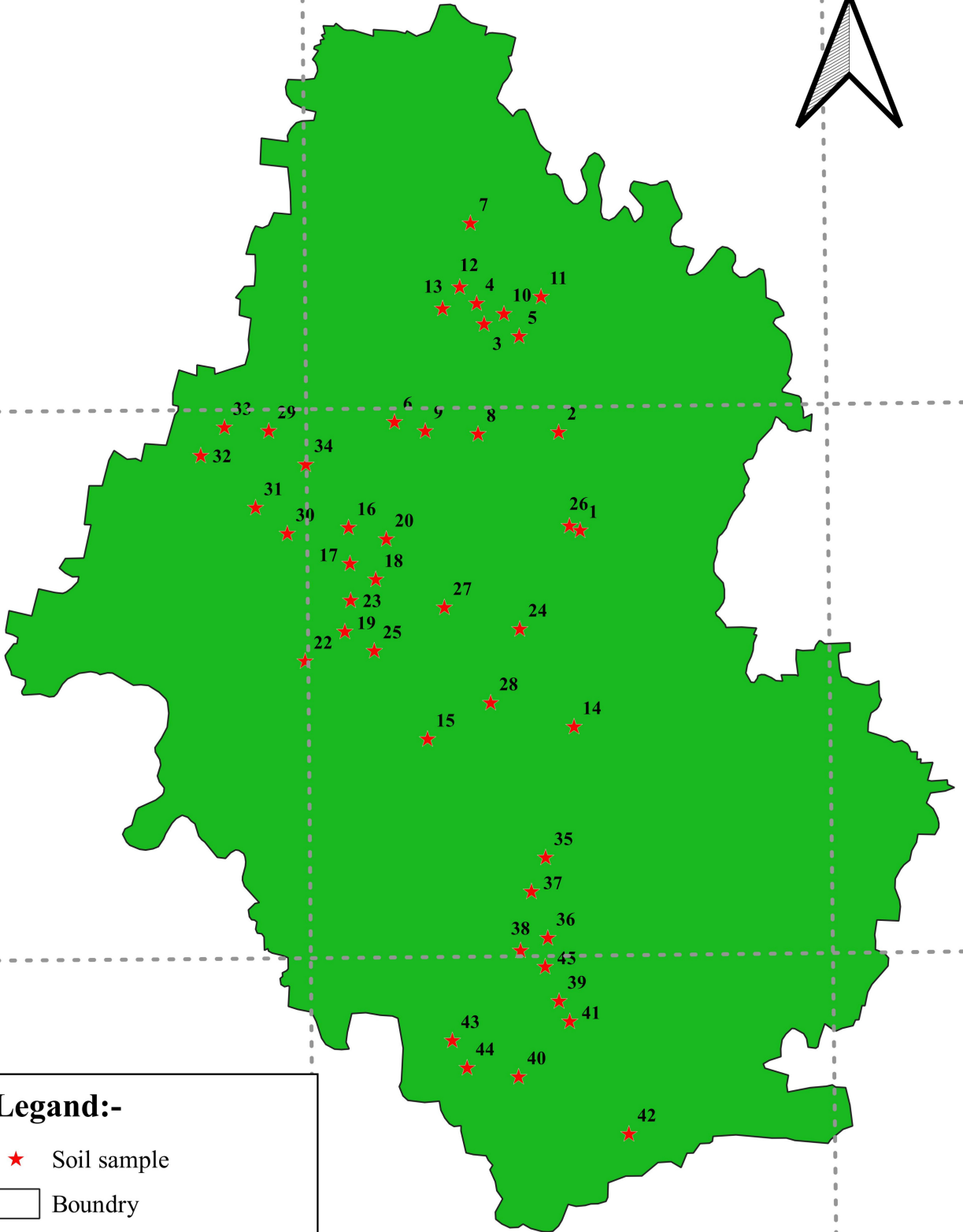
□ Boundry

EC

Safe (<0.8)

Moderately safe (0.8-2.5)

Unsafe (>2.5)



0 7.5 15 km



76°30'0.0"E

77°0'0.0"E

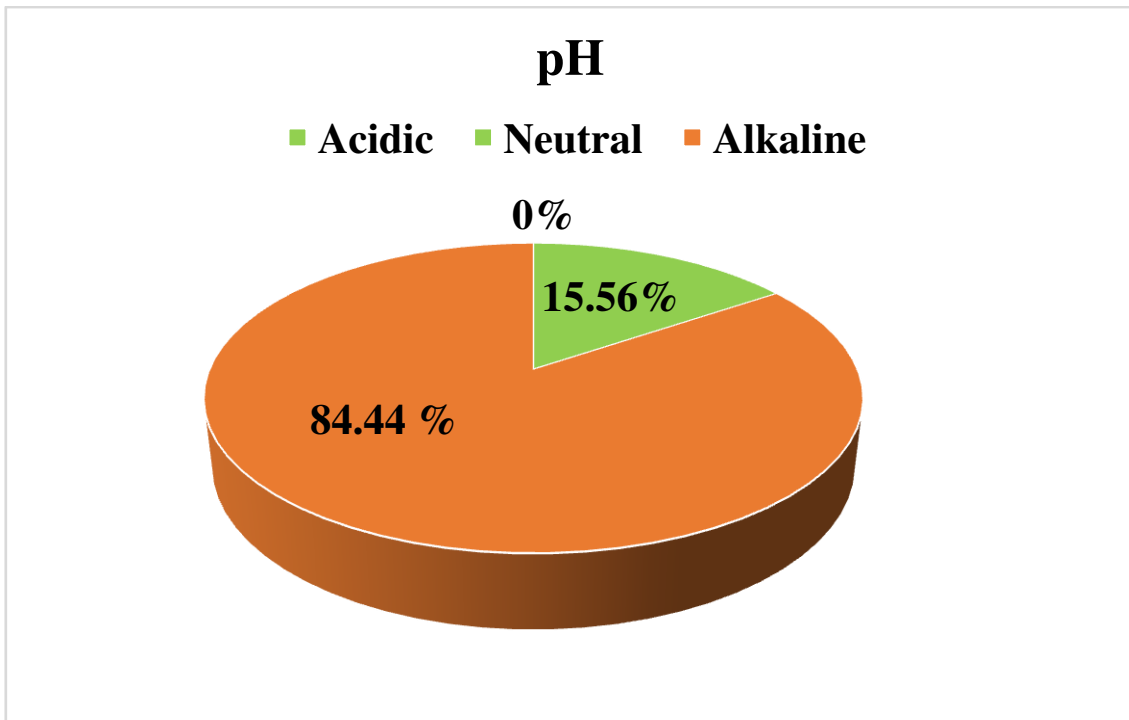


Fig. 4.4: pH of surface soil of study area

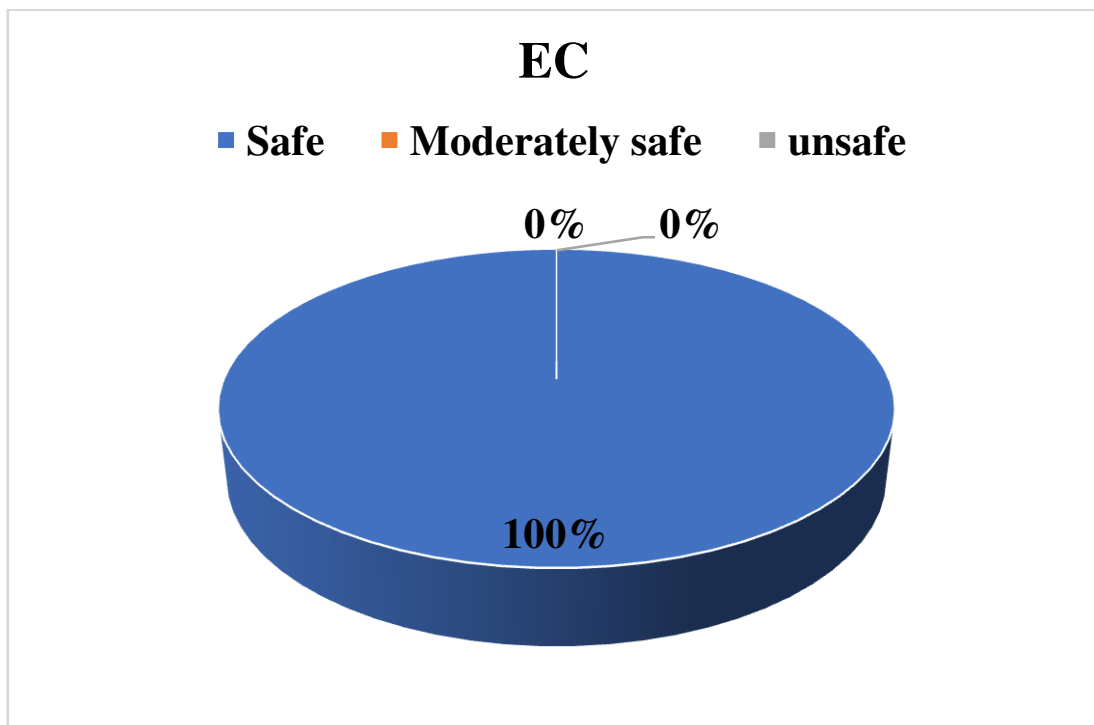
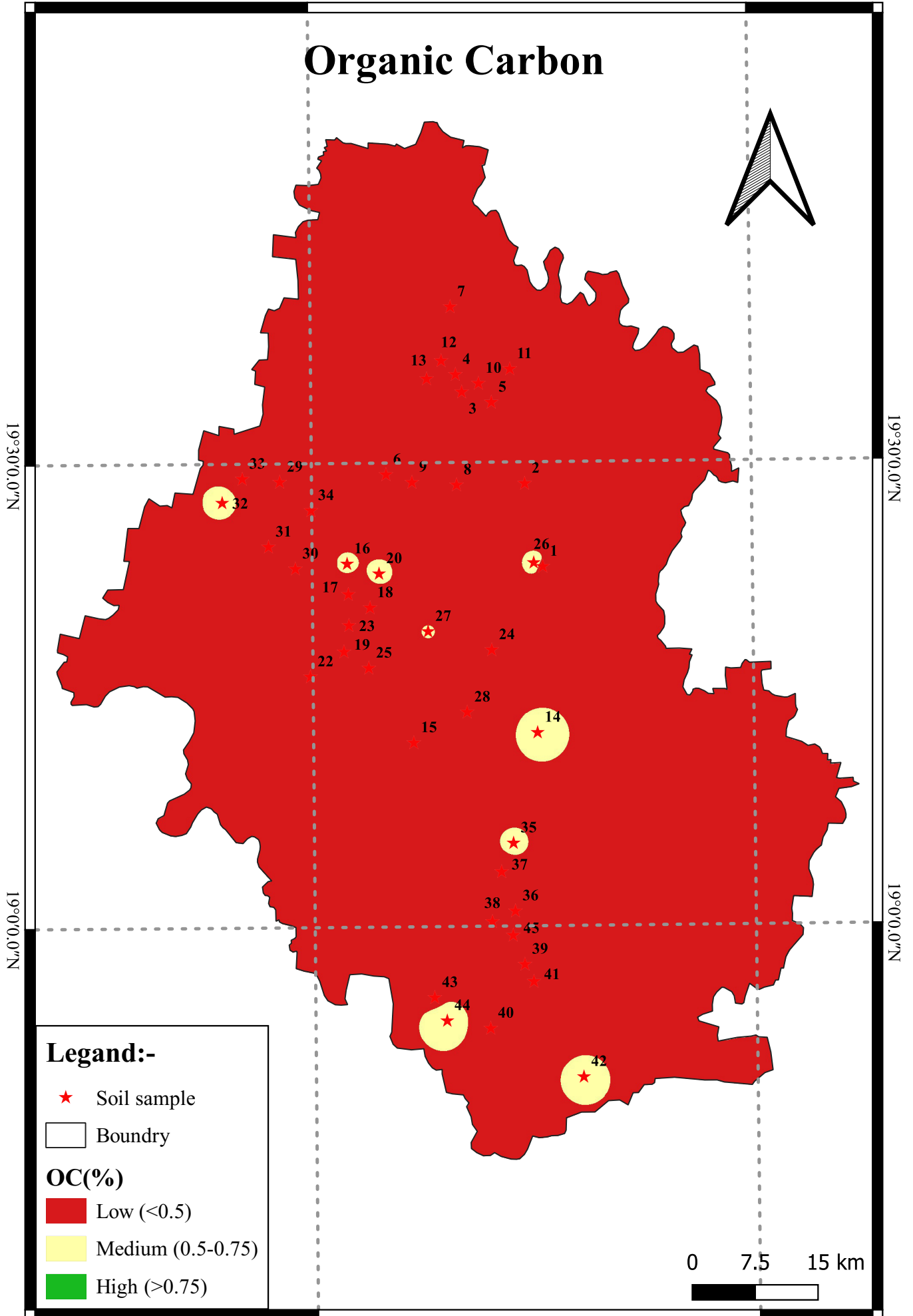
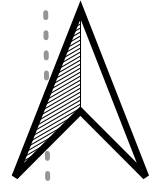


Fig. 4.5: EC of surface soil of study area

76°30'0.0"E

77°0'0.0"E

Organic Carbon



19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N

Legend:-

★ Soil sample

□ Boundry

OC(%)

■ Low (<0.5)

■ Medium (0.5-0.75)

■ High (>0.75)

0 7.5 15 km



76°30'0.0"E

77°0'0.0"E

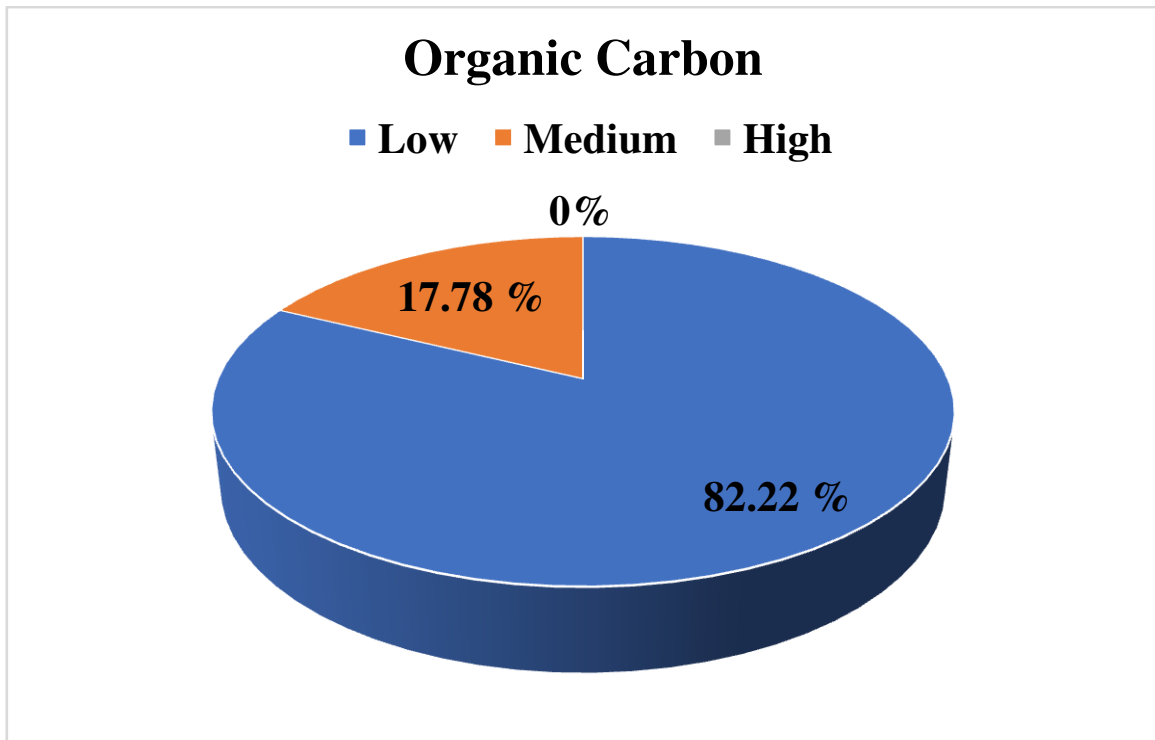


Fig. 4.6: Soil Organic Carbon of surface soil of study area

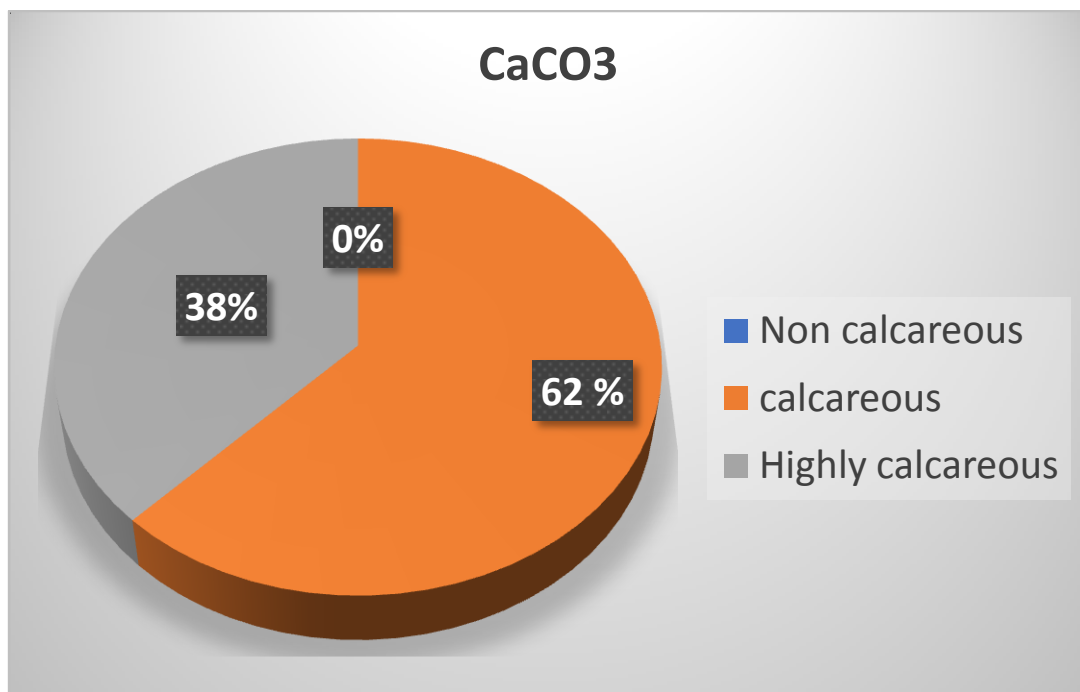


Fig. 4.7: Calcium carbonate of surface soil of study are

The low EC values attributed to well-drained soils which cause leaching of soluble salts from surface layer soils. The results are in confirmatory to findings of Gajbe *et al.* (1976) and normal range of soluble salt present in Marathwada soil was reported.

4.7.1.3 Organic carbon

The soil health and yield of crop bears to improve when increase in soil organic carbon level. Higher soil organic carbon upgrade soil structure or tilth i.e., the greater physical strength of soil. This increases the soil aeration, water drainage, water retention, decreases the threat of erosion and nutrient leaching. Organic matter decomposes more rapidly at higher temperature, so the soils in warmer temperature zone contained low in organic matter than cooler climate soils.

Tillage is one of the major practices that reduce the organic matter level in the soil. The organic carbon content of surface soils was indicated in Table 4.9 and varied from 0.21 to 0.58 per cent with mean value of 0.42 per cent. The total 45 surface samples were collected from study area were falling under medium range of categorization of organic carbon. The soil samples, less than 37 (82.22 %) were coming under low range and 7 (17.78 %) (Fig.4.6). It is observed that the soils of study area contain low to moderate in organic carbon.

High amount of organic carbon content in surface soil is because of addition of organic matter like F Y M or plant residues. The availability of low to medium organic carbon content in soil may be because of high temperature of Marathwada region and less awareness regarding recycling of organic matter and poor management practices. (Ghuge *et al.* 2002).

Similar results were recorded by Shinde (2015) that the soils of oilseed research station, Latur containing low to moderate organic carbon content, Similar results was noticed by Chadar (2017) that the soils of College of Agriculture, Latur farm were observed that as depth increased the per cent of organic carbon was increased and soils were low to moderate in organic carbon content.

4.7.1.4 Calcium carbonate

The excessive calcium uptake by a plant may cause disturbances in ion balance, to the disadvantage of other nutrients (like potassium and magnesium), or to change in cytosol pH and a decrease in solubility of some ions.

Table 4.9: Categorization of cotton growing soils of parbhani district on the basis of ratings of pH, EC, organic carbon and free CaCO₃

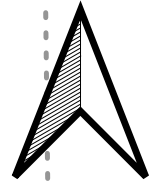
Soil Nutrient Status	No. of Soil Samples	NIV	Category
pH		2.8	High
Acidic	Nil		
Neutral	7		
Alkaline	38		
EC		1	low
Safe	45		
Moderately safe	Nil		
unsafe	Nil		
Organic Carbon		1.17	low
Low	37		
Medium	8		
High	Nil		
CaCO₃		2.3	Medium
Non calcareous	Nil		
calcareous	28		
Highly calcareous	17		

The data on calcium carbonate (CaCO₃) of surface soil samples which was collected from study area are given in Table 4.8, It was revealed that the calcium carbonate content in the surface soil samples were varied from 5.09 to 14.50 per cent with mean value of 9.79 per cent. The total 45 surface samples were collected from study area and out of those samples, 28 (62.22 %) samples are under calcareous and 17 (37.78 %) samples are under highly calcareous range of categorization of calcium carbonate in. (Fig.4.7).

76°30'0.0"E

77°0'0.0"E

Calcium Carbonate



19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N

Legend:-

★ Soil sample

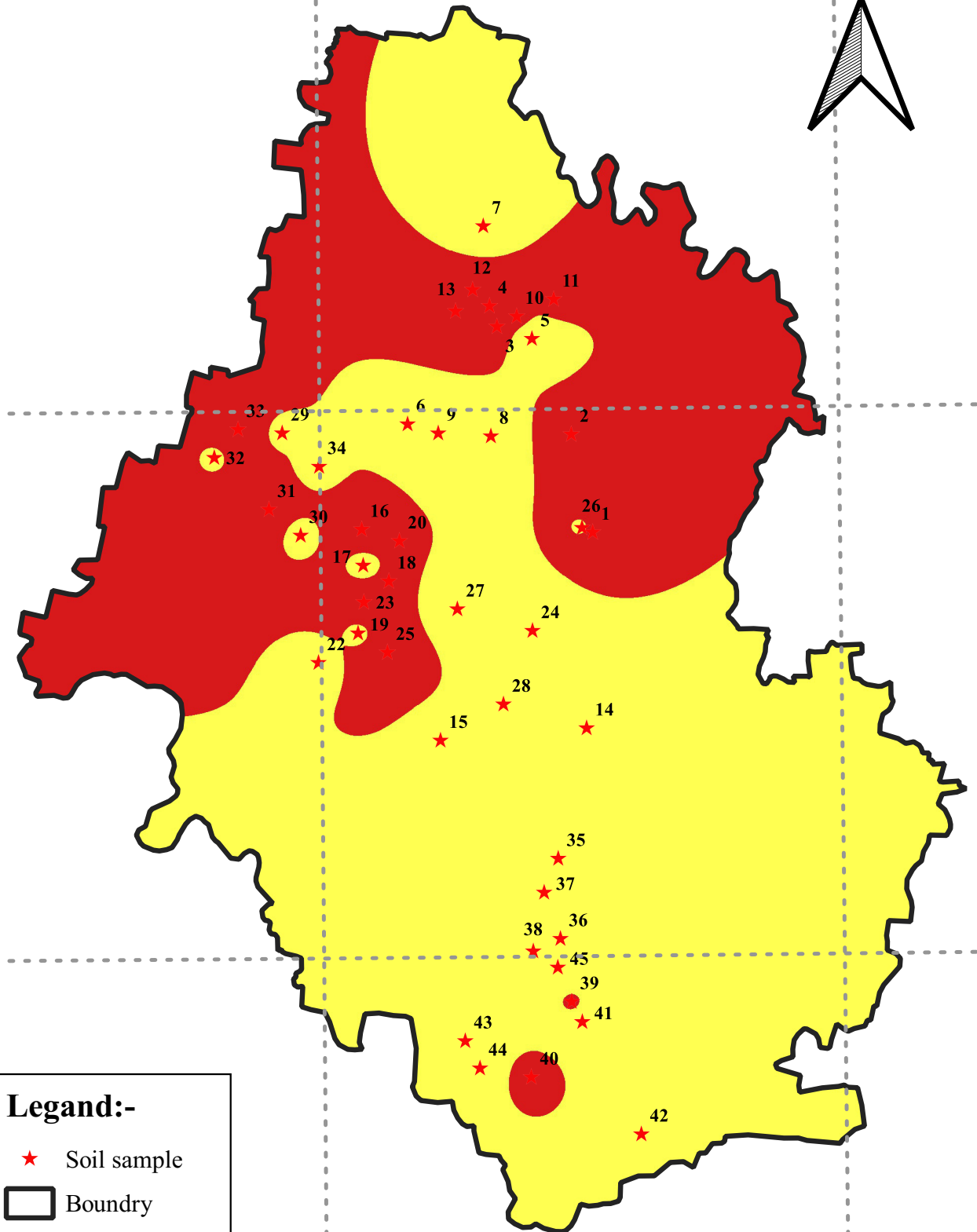
□ Boundry

CaCO₃ (%)

Low (<5)

Medium (5-10)

High (>10)



0 7.5 15 km

76°30'0.0"E

77°0'0.0"E

The higher amount of calcium carbonate content at lower depths than surface layer because of the leaching of calcium carbonate during subsequent rainfall.

Similar results were recorded by Nawkhare (2020) that the calcium carbonate content in soils of Babhalgaon village of Latur district ranged between 6.0 to 13.6 per cent. Similar results were reported by Ghodke (2014) noted that soils of southern tehsils of Parbhani district i.e., Sonpeth, Gangakhed and Palam found to be low to medium in organic carbon with calcareous in nature.

Fertility status of soil

The data in respect of macro nutrient status i.e., nitrogen, phosphorus, potassium and Sulphur of cotton growing soils of Parbhani district are reported as under.

4.7.2 Available macronutrients.

4.7.2.1 Available nitrogen

Soil nitrogen availability can greatly change in both space and time attributes on factors like rainfall, temperature, wind, soil type and pH. Hence, the preferred form in which nitrogen is up taken depends on the plant adaptation to soil conditions and characteristics. The mineralization of organic matter and nitrogen released as plant residues are broken down in the soil and also animal waste is a good source of natural nitrogen in the soil.

The data on available nitrogen of surface soil samples were recorded in Table 4.9 and reported that, the available nitrogen content in surface soil samples was varied from 106.6 to 304.60 kg ha⁻¹ with mean value of 199.14 kg ha⁻¹. The total 45 surface samples were collected from study area and out of above samples, 38 (84.45%) soil samples were categorized under low range and 7 (15.55 %) samples categorized as medium range. The data further showed that the soils were low in available nitrogen content, and surface soils were containing higher nitrogen than sub-surface soil. This is because of the application of nitrogenous fertilizers and organic matter content. It is also associated with hot and dry climate complex, total N reserve and into C; N ratio of immobilized forms of nitrogen.

Similar results were recorded by Chavan (2020) that the turmeric growing soils of basmath tehsil contain 131.08 to 166.86 kg ha⁻¹. Similar results were found by Sutar (2017) and reported that the soils of Zari-Naam River Watershed of Parbhani district showed variation in fertility status. In general majority of soil samples were categorized as low in N and high in K.

Cheke (2012) reported that, available nutrients in soils of Lohara tahsil of Osmanabad district were calcareous in nature and contents low to medium organic carbon. According to nutrient index, values of soils of Lohara tahsil were low in available N, P, S and Zn, while high with respect to available k.

4.7.2.2 Available phosphorus

The phosphorus is very immobile in the soil, it does not move very long in the soil so, get to the roots. The root growth is very important for phosphorus availability to the plant. Any factor that influences the root growth will affect the ability of plant to explore more soil and get sufficient amount of phosphorus to the crop.

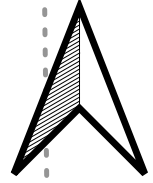
The available phosphorus revealed in Table 4.9 indicated that the available phosphorus content in surface soil samples ranged from 7.90 to 22.30 kg ha⁻¹ with mean value of 13.09 kg ha⁻¹. The total 45 surface samples were collected from study area and out of those samples, 5 (11.11 %) soil samples were coming under low range and 40 (88.89 %) samples were coming under medium range. The data showed that the available phosphorus present in cotton growing soils of Parbhani district was found to moderate in nature. Surface layer of soil contain higher amount of phosphorus than sub-surface layer of soil. These may due to fertilizer application and continuous mining by the crops from soils and higher amount of CaCO₃ present in these soils which get to fix the native and applied phosphorous in soil.

Similar results were recorded by Kshirsagar (2020) that the soils of Vegetable Research Station Scheme V.N.M.K.V Parbhani contained available phosphorus up to 9.24 to 17.21 kg ha⁻¹ with mean value of 12.86 kg ha⁻¹.

76°30'0.0"E

77°0'0.0"E

Available Nitrogen

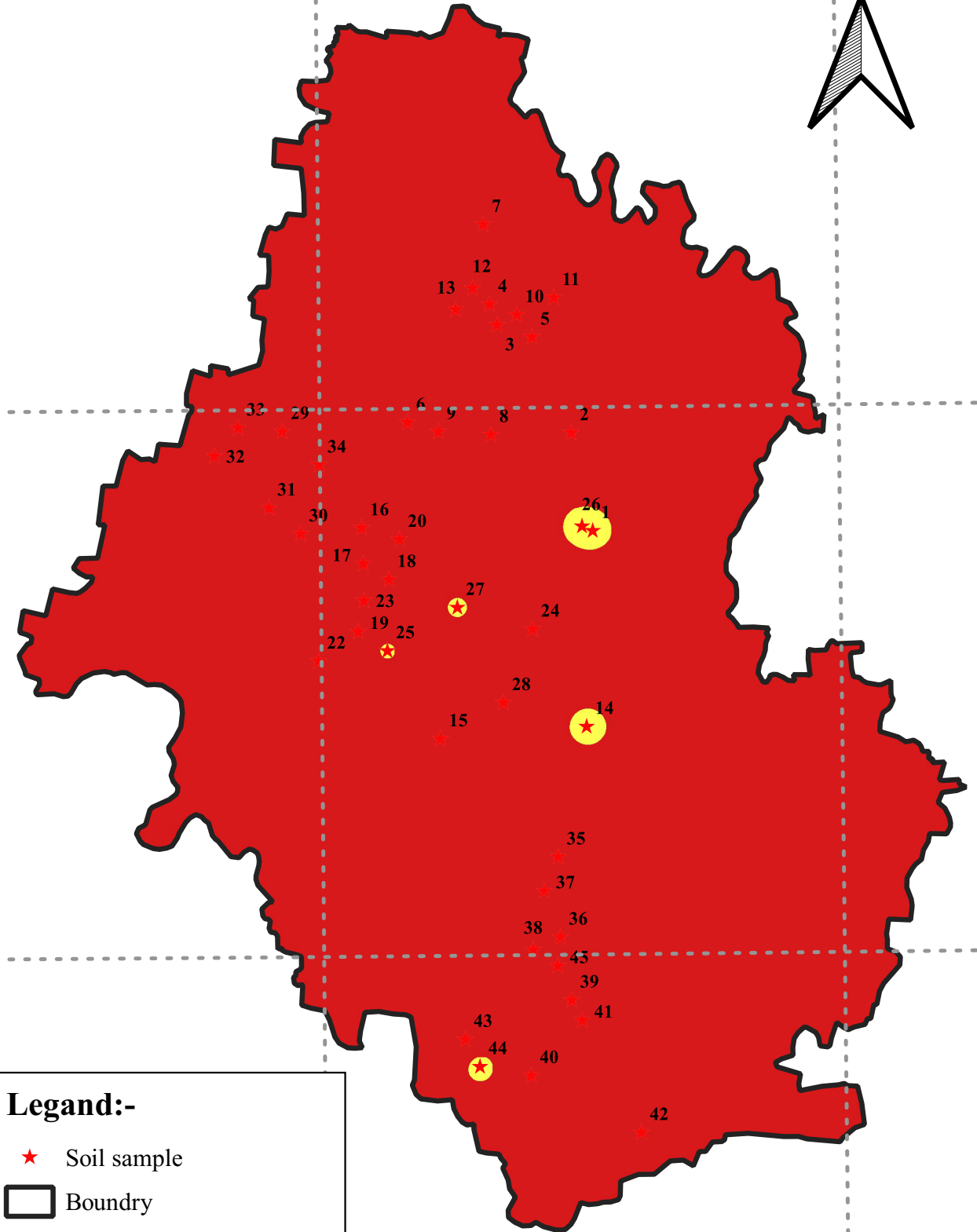


19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N



Legend:-

★ Soil sample

□ Boundry

Available Nitrogen (kg/ha)

Low (<280)

Medium (280-560)

High (>560)

0 7.5 15 km



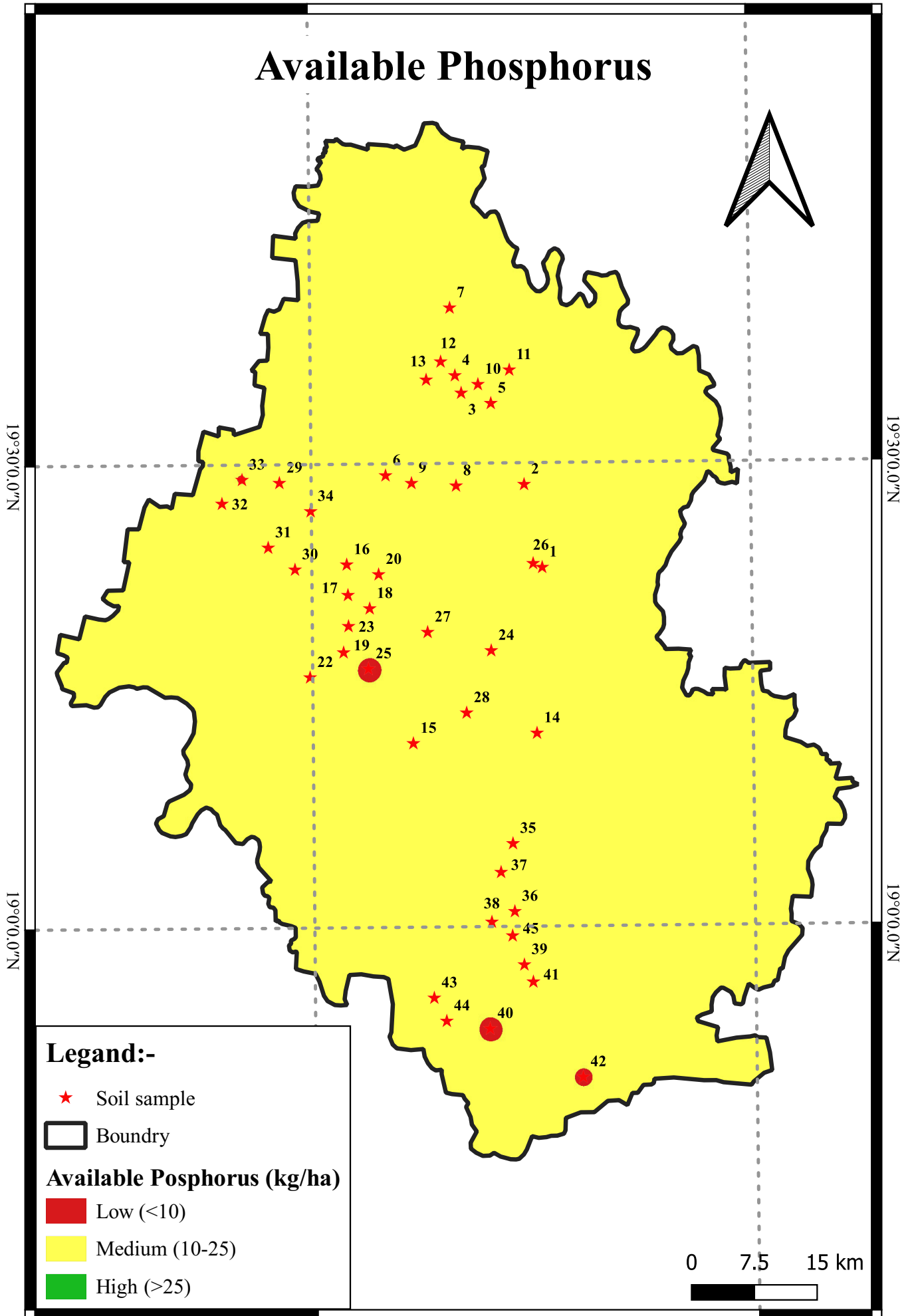
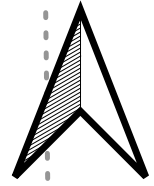
76°30'0.0"E

77°0'0.0"E

76°30'0.0"E

77°0'0.0"E

Available Phosphorus



76°30'0.0"E

77°0'0.0"E

19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N

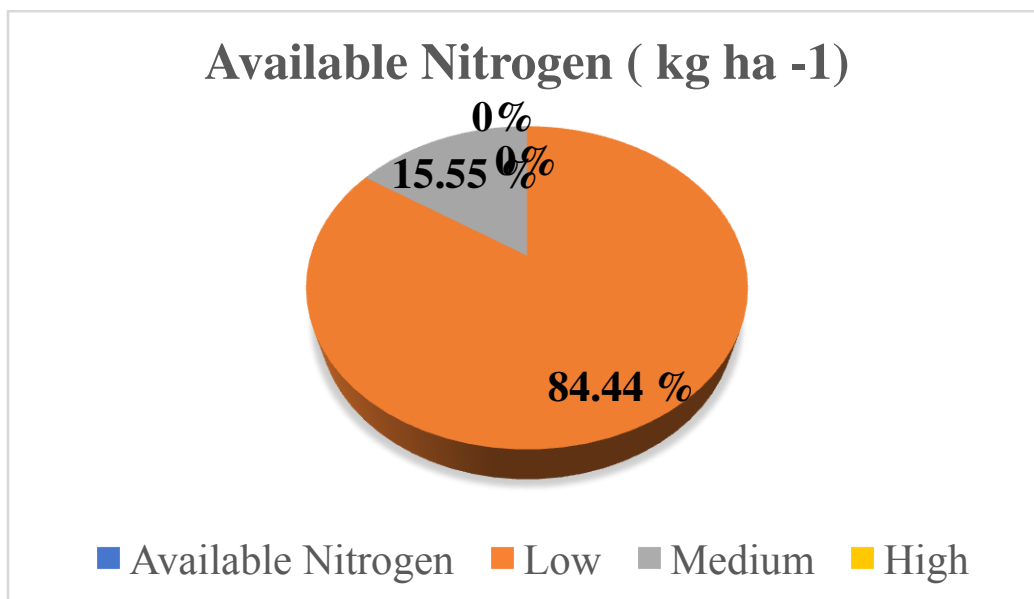


Fig. 4.8: Available nitrogen of surface soil of study area

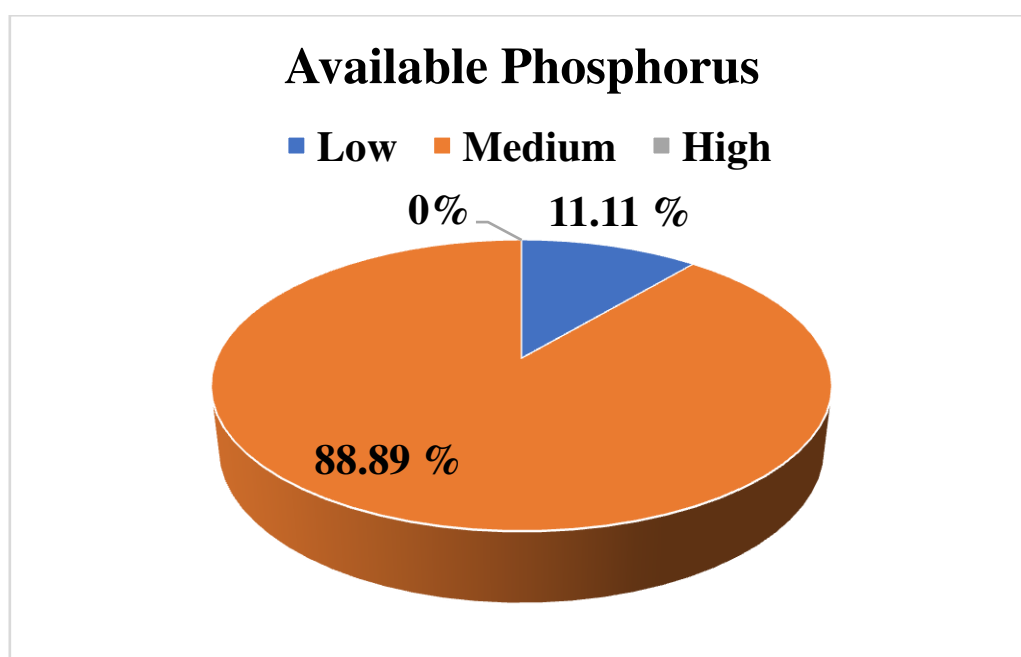


Fig. 4.9: Available phosphorus of surface soil of study area

Table 4.10: Available macronutrients in the soil

Sample No.	N (kg/ha)	P (kg/ha)	K (kg/ha)
1	291.60	11.60	564.80
2	187.50	10.30	583.20
3	176.50	12.30	569.60
4	178.10	9.80	588.00
5	188.10	12.90	659.60
6	169.90	11.60	625.00
7	175.60	13.70	427.20
8	197.50	14.70	458.40
9	189.30	10.90	436.00
10	156.80	14.80	548.80
11	153.60	12.33	458.40
12	144.70	22.30	627.20
13	284.90	21.80	347.20
14	301.20	12.20	558.40
15	106.60	12.10	708.00
16	171.80	13.90	639.20
17	157.90	19.20	537.60
18	135.30	14.60	672.00
19	171.20	13.90	610.40
20	213.20	13.80	772.80
21	172.40	10.10	884.80
22	169.30	19.40	692.80
23	154.80	16.30	903.20
24	146.80	10.30	672.00
25	293.40	7.90	640.00
26	303.60	11.70	624.80
27	294.10	10.80	457.60
28	216.30	10.10	480.00
29	213.20	12.10	470.40
30	206.90	12.10	347.20
31	219.50	15.20	705.60
32	213.20	17.40	604.80
33	216.30	9.80	888.00
34	203.80	10.00	716.80
35	206.90	13.40	414.40
36	197.50	14.30	504.00
37	222.60	15.30	358.40
38	132.40	14.00	425.60
39	185.00	14.00	548.00
40	255.70	9.40	898.00
41	188.40	11.90	328.00
42	178.70	9.90	477.30
43	160.20	10.80	341.50
44	304.60	12.60	263.60
45	154.40	11.70	418.00
Mean	199.14	13.09	565.7

4.7.2.3 Available potassium

The higher content of K₂O in soil was due to presence of the K rich mineral in Vertisols and associated with black soils. The data given in Table 4.9 indicated that the available potassium content in surface soils from study area varied from 263.6 to 903.20 kg ha⁻¹ with a mean value of 565.7 kg ha⁻¹. The total 45 surface samples were collected from study area and out of those samples, 5 (11.11 %) soil sample was coming under medium and 40 (88.89 %) soil samples were under the high range of categorization of available potassium in the soil. (Fig.4.10) The data indicated that the soils of study area contained very high amount of available potassium. The high content of available potassium in these soils mainly associated with the presence of K rich mineral in Vertisols and associated black soils. Similar results were obtained by Chavan (2020) that the turmeric growing soils of Basmat tehsil contain 405.93 to 587.44 kg ha⁻¹ potassium and with mean value of 485.99 kg ha⁻¹. Soils of cotton growing of Parbhani district were categorized in various categories as per three tier system of nutrient indexing and the related data is presented in Table 4.11

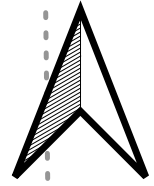
Table 4.11: Categorization of soils of study area on the basis of available nitrogen, phosphorus and potassium

Soil Nutrient Index	No. of Soil Samples	NIV	Category
Available Nitrogen		1.15	low
Low	38		
Medium	7		
High	Nil		
Available Phosphors		1.8	Medium
Low	5		
Medium	40		
High	Nil		
Available Potassium		2.97	High
Low	Nil		
Medium	5		
High	40		

76°30'0.0"E

77°0'0.0"E

Available Potassium



19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N

Legend:-

★ Soil sample

□ Boundry

Available K Potassium (kg/ha)

Low (<120)

Medium (120-280)

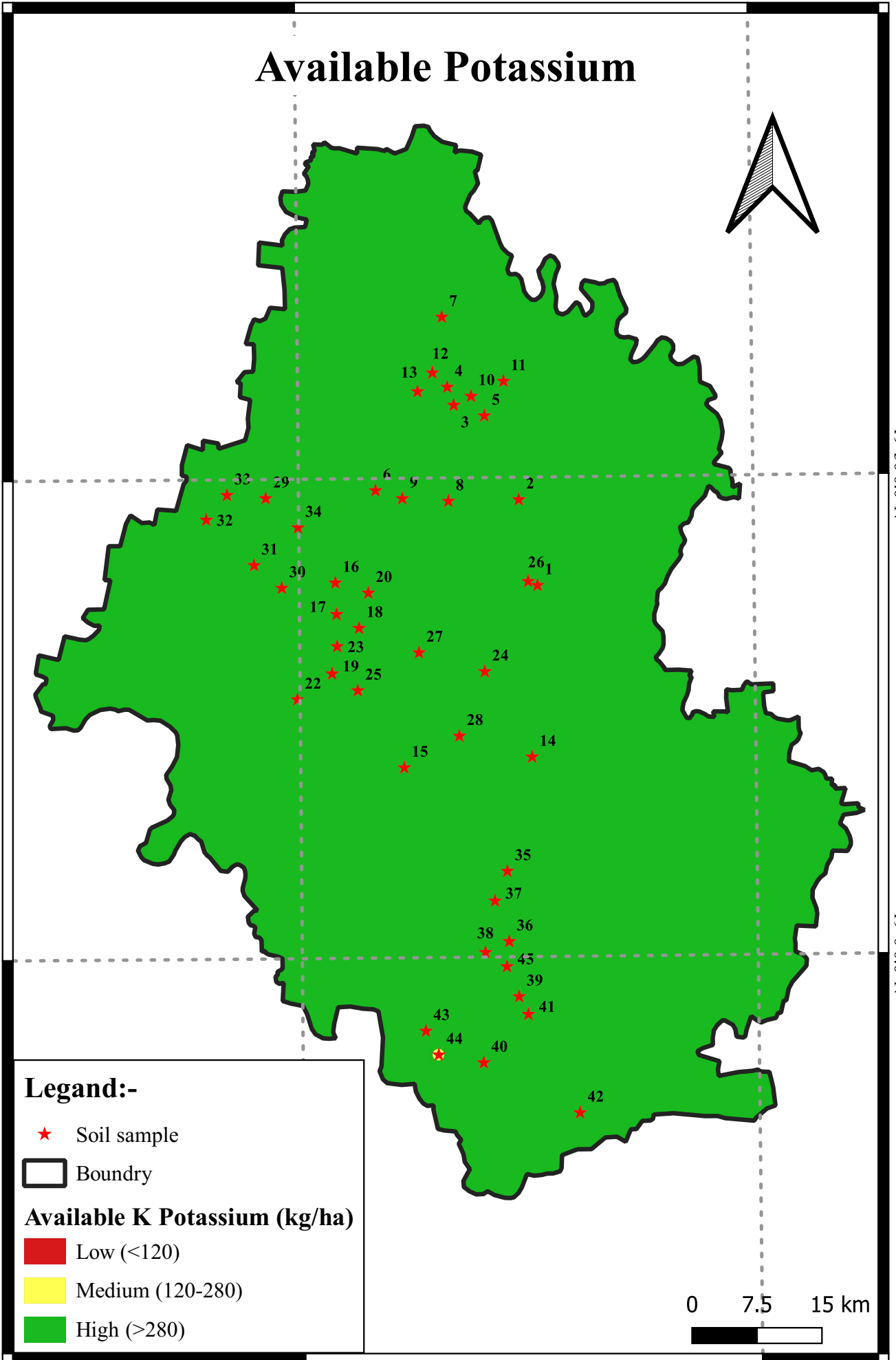
High (>280)

0 7.5 15 km



76°30'0.0"E

77°0'0.0"E



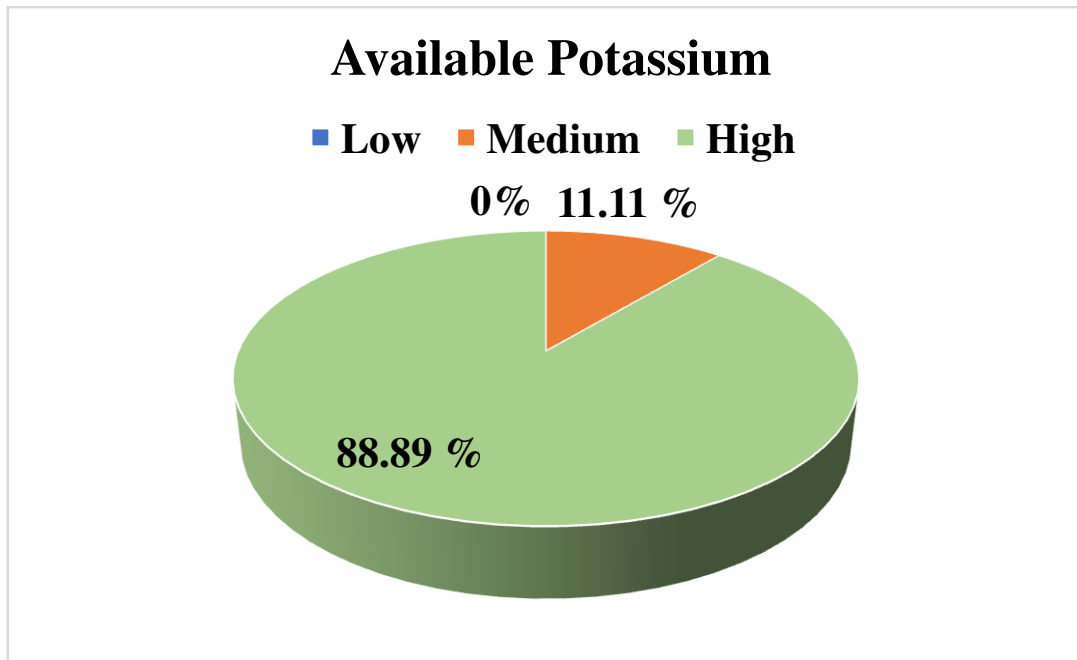


Fig. 4.10: Available potassium of surface soil of study area

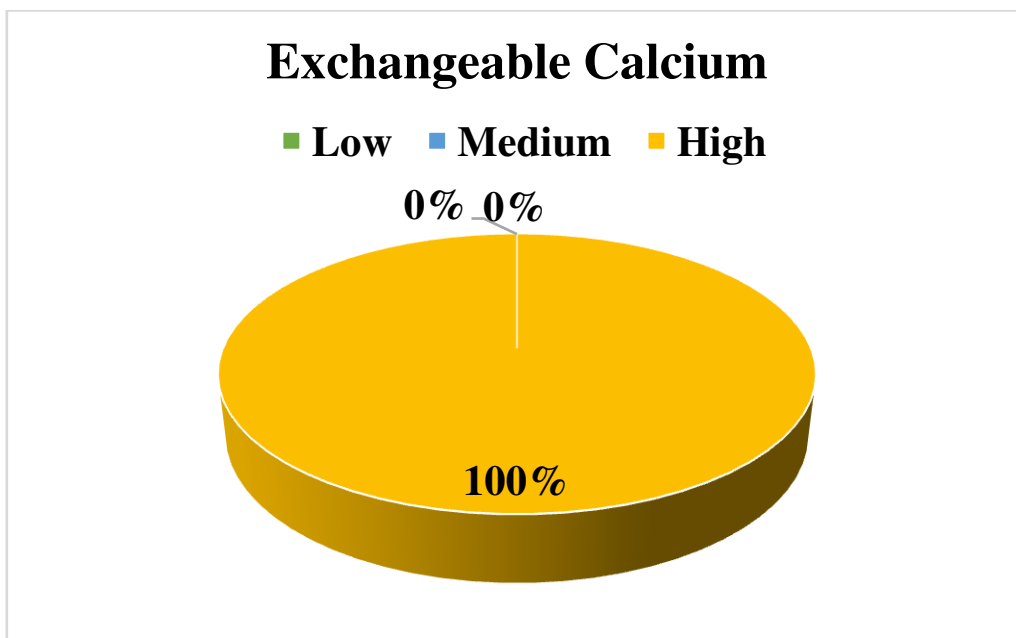


Fig. 4.11: Exchangeable Calcium of surface soil of study area

4.7.2.4 Status of exchangeable calcium, magnesium and available sulphur in soil

The data emerged out from analysis of 45 surface soil samples from cotton growing soils of Parbhani district on secondary nutrients i.e exchangeable calcium (Ca^{++}), magnesium (Mg^{++}) and available sulphur is given in Table 4.12.

4.7.2.5 Exchangeable calcium and magnesium

Exchangeable calcium content in soils of study area varied from 29.04 to 35.66 $\text{cmol (p}^+) \text{ kg}^{-1}$. The lowest exchangeable calcium 29.04 $\text{cmol (p}^+) \text{ kg}^{-1}$ was observed and highest exchangeable calcium 35.66 $\text{cmol (p}^+) \text{ kg}^{-1}$ recorded from surface soil samples collected from study area. However, exchangeable magnesium content in soils of study area between 15.84 to 25.74 $\text{cmol (p}^+) \text{ kg}^{-1}$. The lowest exchangeable magnesium 15.84 $\text{cmol (p}^+) \text{ kg}^{-1}$ was observed and highest exchangeable magnesium 25.74 $\text{cmol (p}^+) \text{ kg}^{-1}$ with an average of 20.05 $\text{cmol (p}^+) \text{ kg}^{-1}$ of soils area in study. It was also observed that the soils were high in exchangeable magnesium which was recorded in surface soil samples

The data emerged out showed that, all soil samples were high in exchangeable Ca and Mg. Available sulphur content of these soils were 23 (51.12 %) in high category and 22 (48.88 %) samples were found in medium category of soil available sulphur. (Fig.4.11)

In general soils of study area in case of exchangeable calcium were ranged from 29.04 to 35.66 $\text{cmol (p}^+) \text{ kg}^{-1}$ with an average of 30.58 $\text{cmol (p}^+) \text{ kg}^{-1}$ and all the soil samples were recorded as high in exchangeable calcium due to presence of calcium dominant cation in all the categories of the soils and calcareous nature of soil. Kawde *et al.* (2005) also reported that, exchangeable calcium content in these soils of Keliveli, district Akola varied from 18.2 to 35.2 $\text{cmol (P}^+) \text{ kg}^{-1}$.

In case of exchangeable magnesium, soils of study area ranged from 15.84 to 25.74 $\text{cmol (p}^+) \text{ kg}^{-1}$ with an average of 20.05 $\text{cmol (p}^+) \text{ kg}^{-1}$ and all the soil samples were recorded high in exchangeable magnesium. (Fig.4.12). It might be due to presence of clay and dolomitic parent material. Bacchewar and Gajbhiye (2011) studied status of secondary nutrients and other properties in soils of Latur District of Maharashtra and recorded that available Mg content was ranged between 7.0 to 36.0 $\text{cmol (p}^+) \text{ kg}^{-1}$ with mean values of 20 $\text{cmol (p}^+) \text{ kg}^{-1}$. The soil samples from Latur district showed high content of exchangeable Mg. Similar findings were also reported by Medhe *et al.* (2012).

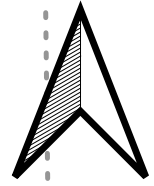
Table No.4.12: Exchangeable calcium (Ca⁺⁺), magnesium (Mg⁺⁺) and available sulphur in cotton growing soils of Parbhani district.

Sample No.	S (mg/ kg)	Exchangeable Ca ⁺⁺ (cmol(p+) kg-1)	Exchangeable Mg ⁺⁺ (cmol(p+) kg-1)
1	8.50	30.69	16.17
2	7.60	31.68	15.84
3	7.30	29.37	19.47
4	6.70	29.04	22.44
5	12.60	30.03	19.8
6	13.44	29.85	18.42
7	11.31	33	15.84
8	12.05	32.34	15.84
9	14.91	31.68	19.14
10	11.20	31.35	20.46
11	7.40	32.01	19.14
12	11.90	31.96	17.86
13	8.90	29.04	25.08
14	12.03	29.7	23.1
15	11.50	30.36	21.12
16	11.36	29.37	21.12
17	12.66	30.03	20.13
18	11.03	31.35	25.74
19	11.38	32.67	22.77
20	8.93	31.68	22.11
21	6.08	33	21.12
22	11.90	33	19.8
23	7.43	33.33	18.15
24	12.60	32.01	18.15
25	5.91	32.34	20.79
26	13.46	33	17.82
27	6.91	32.94	19.24
28	9.32	33.66	17.49
29	7.41	32.34	18.48
30	8.23	33.33	16.5
31	8.74	32.01	17.49
32	10.34	32.67	18.81
33	9.18	35.31	20.13
34	7.24	33.66	19.14
35	5.60	33.33	17.49
36	8.50	32.34	22.11
37	10.21	33	18.48
38	8.80	30.03	24.09
39	9.03	31.68	19.8
40	11.26	32.34	20.79
41	9.80	32.67	19.14
42	8.81	31.02	22.44
43	11.49	29.37	17.82
44	10.47	30.03	17.49
45	10.99	31.68	17.82
Mean	9.83	31.71	19.60

76°30'0.0"E

77°0'0.0"E

Exchangeable Calcium



19°30'0.0"N


19°30'0.0"N

19°0'0.0"N

19°0'0.0"N


Legend:-

 Boundry

 Soil sample

Exchangeable Ca (cmol(p+)/kg)

 Low (<0.1)

 Medium (0.1-1)

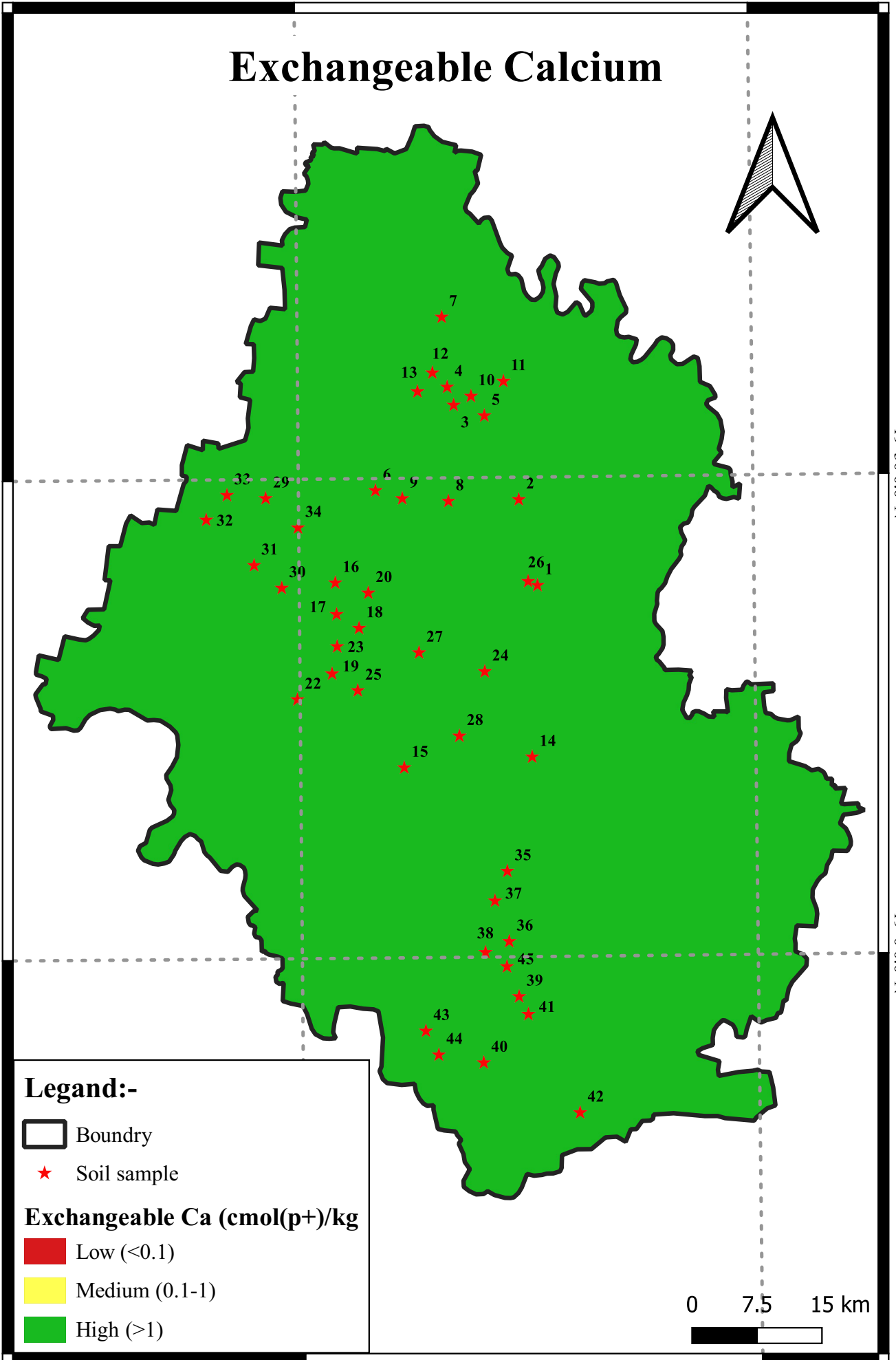
 High (>1)

0 7.5 15 km



76°30'0.0"E

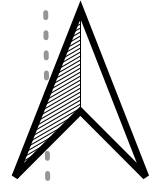
77°0'0.0"E



76°30'0.0"E

77°0'0.0"E

Exchangeable magnesium



19°30'0.0"N


19°30'0.0"N

19°0'0.0"N


19°0'0.0"N


Legend:-

 Boundry

 Soil sample

Exchangeable Mg (cmol(p+)/kg)

 Low (<0.04)

 Medium (0.04-0.33)

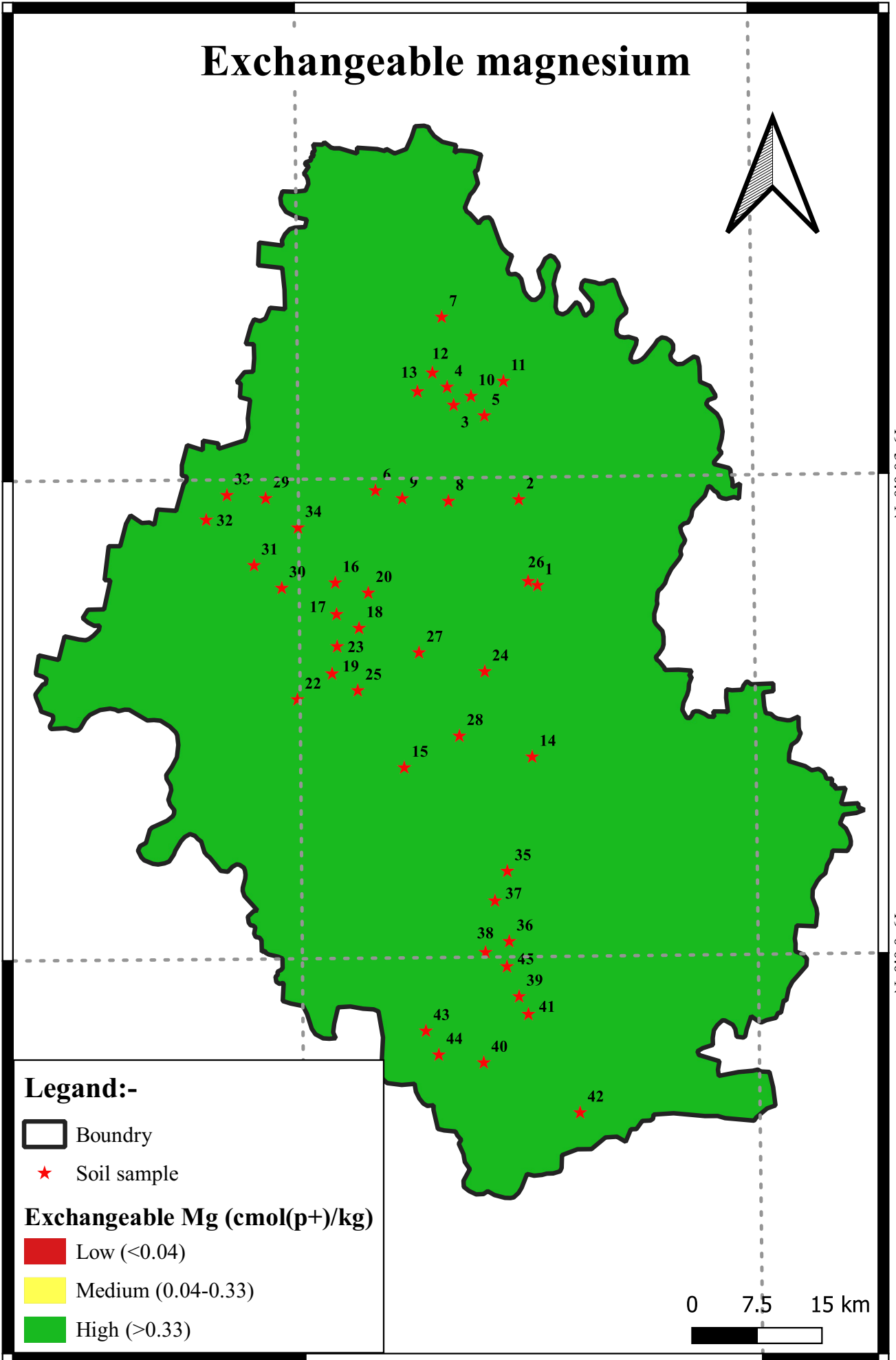
 High (>0.33)

0 7.5 15 km



76°30'0.0"E

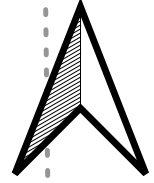
77°0'0.0"E



76°30'0.0"E

77°0'0.0"E

Available Sulphur



19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N

Legend:-

★ Soil sample

□ Boundry

Available Sulphur (mg/kg)

Low (<5)

Medium (5-10)

High (>10)

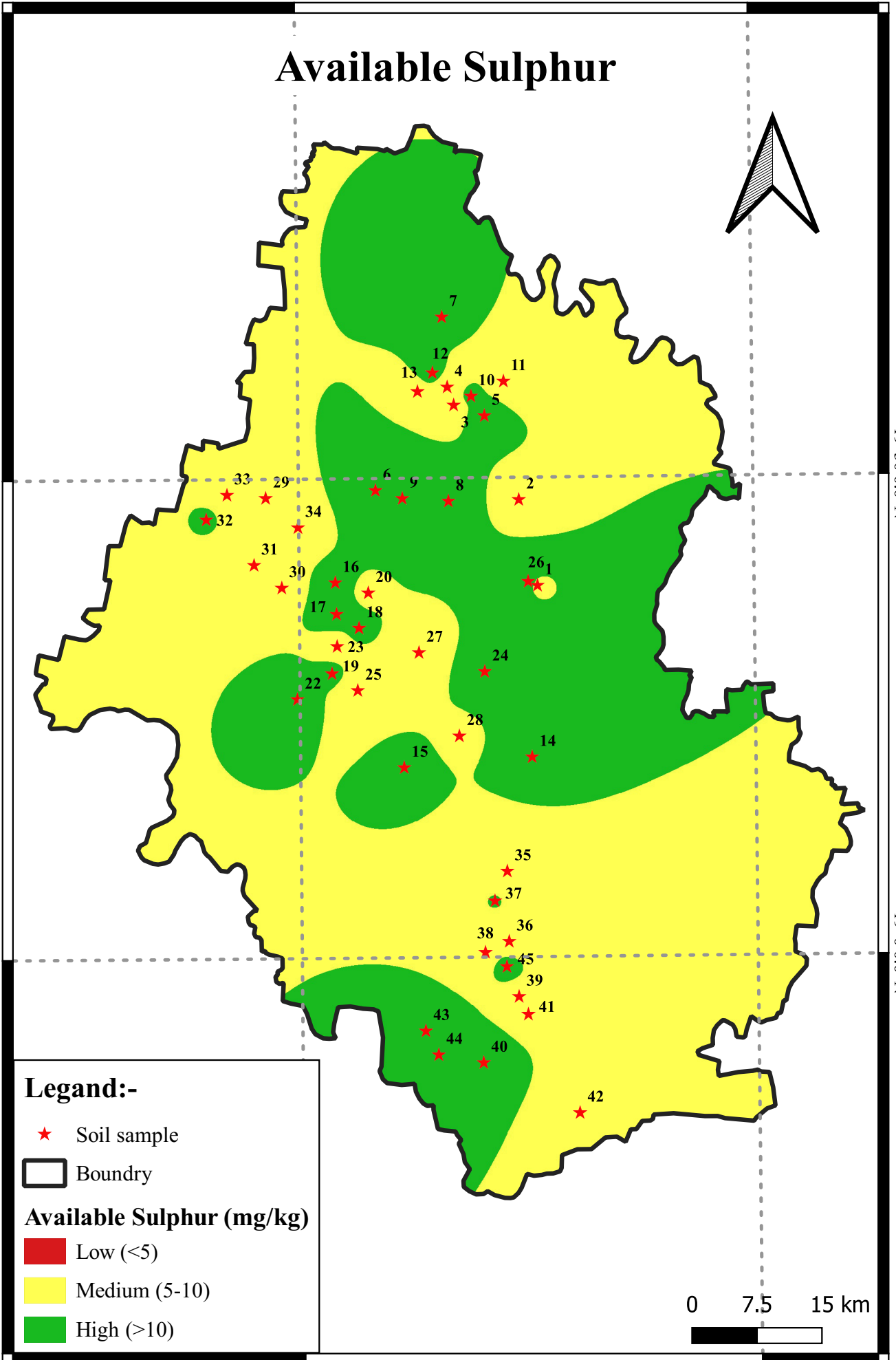


0 7.5 15 km



76°30'0.0"E

77°0'0.0"E



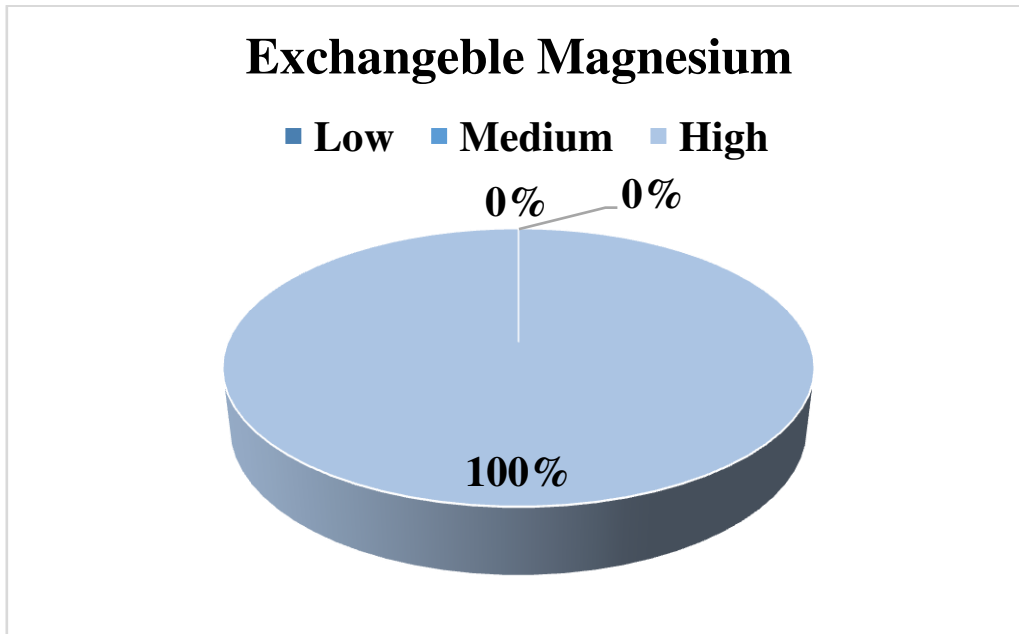


Fig. 4.12: Exchangeable Magnesium of surface soil of study area

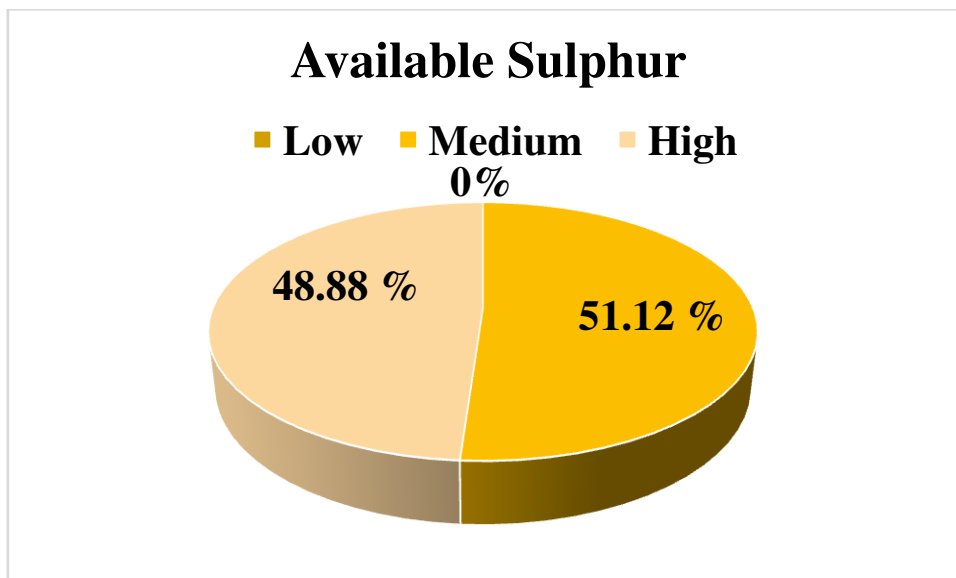


Fig. 4.13: Available sulphur of surface soil of study area

4.7.2.6 Available sulphur

The data revealed in Table 4.11, showed the available sulphur content in surface soils of study area varied from 5.6 to 14.91 mg kg⁻¹ with mean of value 9.83 mg kg⁻¹. The total 45 surface samples were collected from study area and out of that samples, 23 (51.12 %) samples were under medium and 22 (48.88 %) samples under the high range of categorization of available sulphur in the soil. (Fig.4.13). The data indicated that the available sulphur contain in cotton growing soils of Parbhani district were moderate in nature.

Surface layer of soil contain higher amount of sulphur than sub-surface layer of soil and these may due to S containing fertilizer application. Malewar and Ismail (1996) reported the critical limit of available sulphur i.e 10.7 mg kg⁻¹ for soils of Maharashtra.

Similar results were obtained by Nawkhare (2020) that the available sulphur content in soils of Babhalgaon village of Latur district ranged from 3.80 to 9.85 mg kg⁻¹.

Table 4.13: Categorization of soils of study area for exchangeable calcium, magnesium and available sulphur

Soil Nutrient Index	No. of Soil Samples	NIV	Category
Exchangeable Calcium		3	High
Low	Nil		
Medium	Nil		
High	45		
Exchangeable Magnesium		3	High
Low	Nil		
Medium	Nil		
High	45		
Available Sulphur		2.48	Moderate
Low	Nil		
Medium	23		
High	22		

Categorization of exchangeable calcium, magnesium and available sulphur in soils of study area were categorized in various categories as per three tier system of nutrient indexing and the related data is presented in Table 4.13.

4.7.3 Available micronutrients in cotton growing soils of Parbhani District.

Cotton requires both major and micronutrients for proper growth and development. Out of many micronutrients, the available four nutrients are important Fe, Mn, Cu and Zn and found to affect on growth and yield of the crop. Though iron is not a constituent of chlorophyll, it is essential for its synthesis. It acts as catalyst in enzyme action in plant metabolism. Manganese is essential for chlorophyll synthesis. Copper is a constituent of several enzymes' participation in the cellular oxidation-reduction processes, zinc is taking part in the biosynthesis of a plant hormone. It also plays role nucleic acid, protein and chlorophyll synthesis.

The available micronutrient content in surface layer is found to be more than sub surface layers. This may be due to surface application of micronutrients and to presence of minerals like feldspar, magnetite, hematite and limonite which together constitute bulk of trap rock in these soils.

4.7.3.1 DTPA Extractable Iron

Poor soil aeration which reduces the oxygen level in the soil, which is due to flooding or compaction of soil.

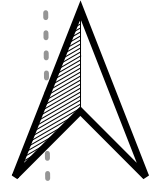
The soil samples collected from cotton growing soils of Parbhani showed variation in DTPA extractable iron (Fe). The data revealed in Table 4.13, indicated that the DTPA extractable iron content in the surface soils of study area varied from 2.67 to 33.04 mg kg⁻¹ with a mean value of 10.59 mg kg⁻¹. The total 45 surface samples were collected from study area and out of that, 1 (2.23 %) sample was under medium and 44 (97.77 %) samples were under high range of available ferrous (Fig.4.14). The data showed that the content in the soils of study area were high in nature. This is because of high content of ferromagnesian minerals present in the soil and ferrous ammonium sulphate fertilizer application.

Similar results were reported by Cheke, (2012) and noticed that DTPA-Fe was in the range of 0.82 to 9.36 mg kg⁻¹ in surface soils of Northern Maharashtra.

76°30'0.0"E

77°0'0.0"E

Available Iron



19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N

Legend:-

★ Soil sample

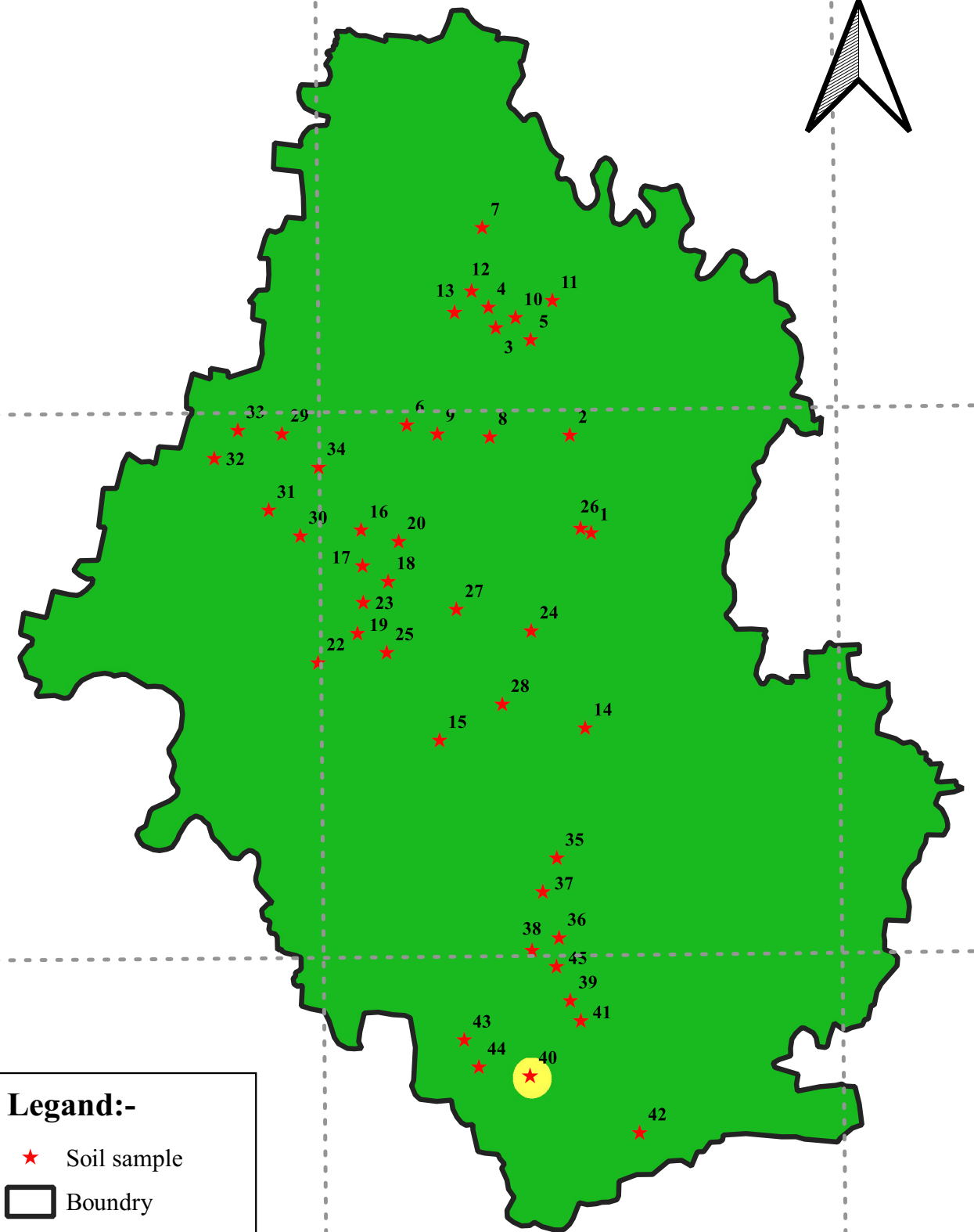
□ Boundry

Available Fe (ppm)

Low (<2.5)

Medium (2.5-4.5)

High (<4.5)



0 7.5 15 km

76°30'0.0"E

77°0'0.0"E

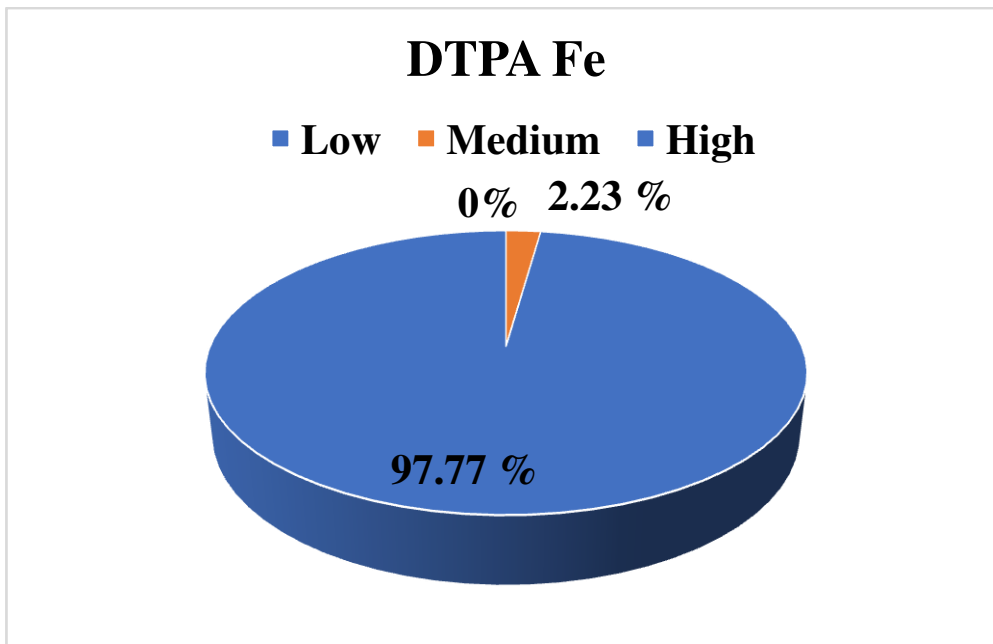


Fig. 4.14: DTPA Fe of surface soil of study area

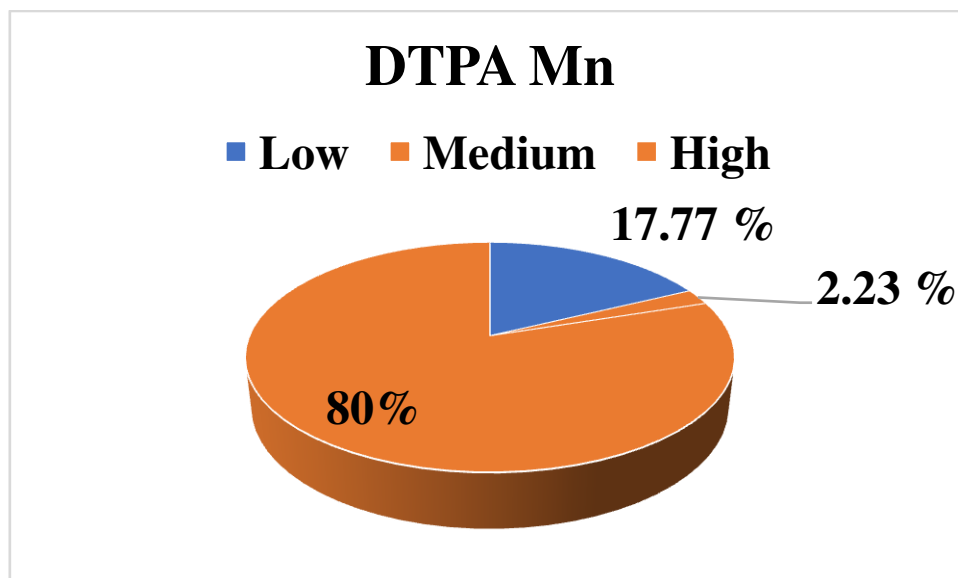
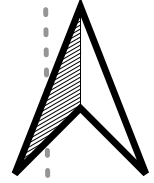


Fig. 4.15: DTPA Fe of surface soil of study area

76°30'0.0"E

77°0'0.0"E

Available Manganese



19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N

Legend:-

Boundry

Soil sample

Available Mn (ppm)

Low (<2)

Medium (2-5)

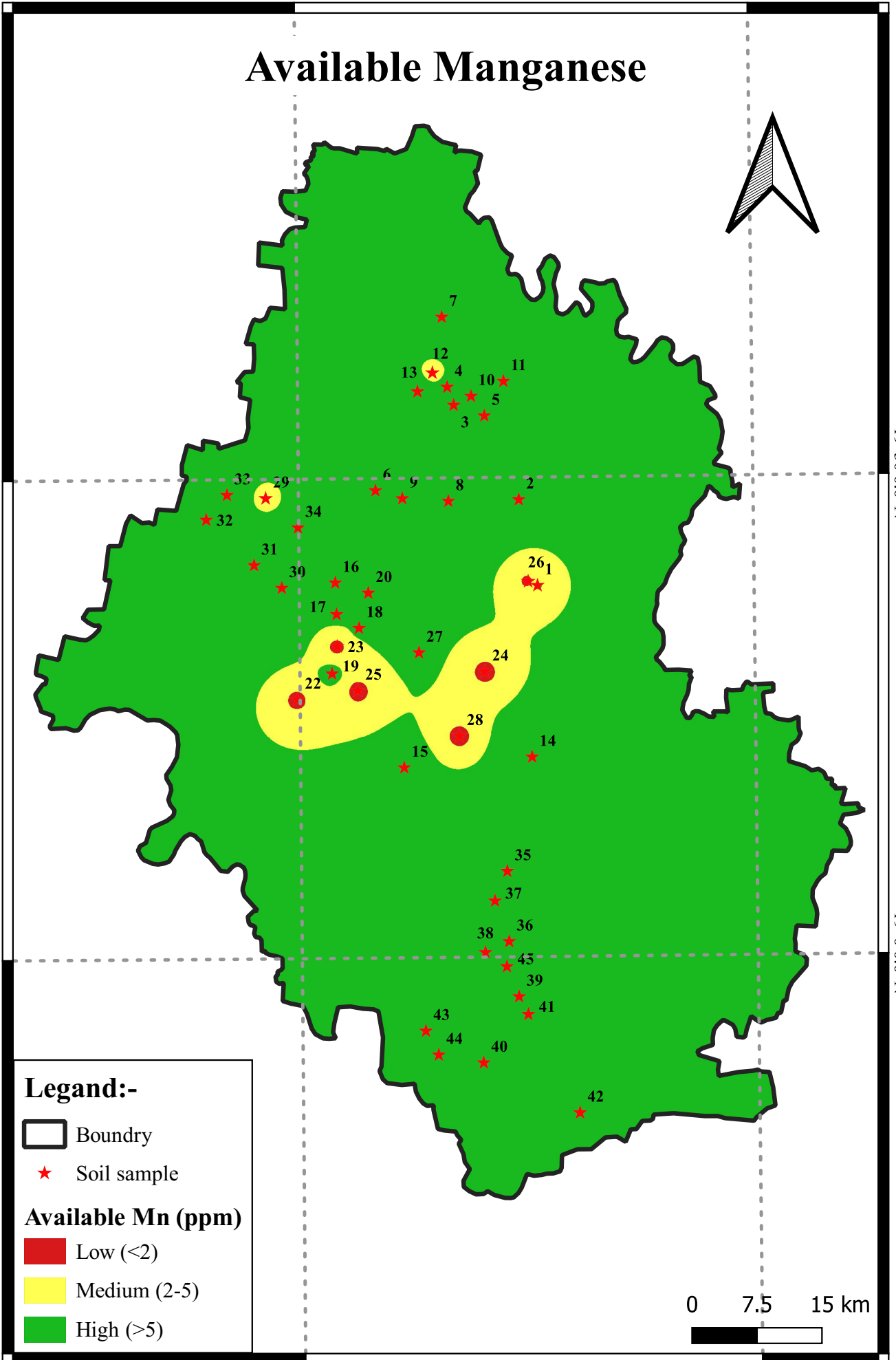
High (>5)

0 7.5 15 km



76°30'0.0"E

77°0'0.0"E



4.7.3.2 DTPA Extractable Manganese

DTPA extractable Mn content of surface soil samples which are collected from cotton growing soils of Parbhani District is revealed in Table 4.12. The data stated that the DTPA Mn content in the surface (0-30 cm) soil samples was ranged from 0.98 to 17.04 mg kg⁻¹ with mean value of 8.00 mg kg⁻¹. The total 45 surface samples were collected from study area and out of these samples, 8 (17.77 %) soil samples were under low range, 1 (2.23 %) and 36 (80%) samples were under the high range of categorization of available manganese in the soil. (Fig.4.15)

It was found that the DTPA extractable Mn content of study area was higher. Mandavgade *et al.* (2015) recorded that, the relative higher content of DTPA-Mn in the soils might be due to the soils derived from basaltic parent material which contained higher ferromagnesian minerals.

4.7.3.3 DTPA Extractable Zinc

DTPA extractable Zn content of surface soil samples which are collected from study area is given in Table 4.12. It indicated that the DTPA Zn present in the surface (0-30cm) soil samples were ranged from 0.19 to 10.49 mg kg⁻¹ with mean value of 1.26 mg kg⁻¹. The total 45 surface samples were collected from study area and out of that samples, 28 (62.21 %) soil samples were under low range, 11 (24.44 %) samples were under medium and 6 (13.33 %) samples under the high range of categorization of available zinc in soil. (Fig.4.16) The available zinc present in soils of study area were low in nature. It may be due to high clay content and calcareous nature of soils.

Gajabe *et al.*, (1976) also reported that the DTPA extractable zinc in the soils of Parbhani district was varied from 0.8 to 6.4 mg kg⁻¹ and cuprite minerals in soils and basaltic parent materials. Similar results were found by Mandavgade in (2014) and reported that, the nutritional status of Northern tehsils of Parbhani district (Jintur, Selu and Pathri) soils were analysis low to medium organic carbon with non-calcareous to calcareous in nature, and available Zn nutrients is in low range.

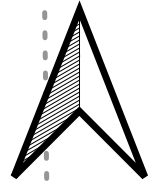
4.14: Available micronutrients in the cotton growing soils of Parbhani district

Sample No.	Fe (mg/ kg)	Mn (mg/ kg)	Zn (mg/ kg)	Cu (mg/ kg)
1	9.02	5.27	1.37	1.03
2	8.08	5.28	1.01	1.04
3	9.46	5.37	1.62	1.22
4	8.02	5.79	0.22	1.09
5	9.64	5.99	1.26	1.2
6	9.86	5.9	0.21	1.43
7	10.07	12.9	1.87	1.18
8	10.74	15.78	2.93	4.89
9	9.82	12.56	0.36	1.06
10	9.93	10.35	0.19	1.19
11	8.57	10.86	0.44	1.8
12	10.6	1.86	0.52	1.24
13	11.09	13.87	0.31	1.34
14	9.43	11.03	1.96	1.92
15	7.93	7.03	0.26	1.1
16	8.92	5.29	1	1.3
17	10.03	5.31	3.06	1.2
18	8.13	5.32	1.38	1.51
19	15.18	6.03	1.63	1.63
20	14.06	8.49	1.08	2.5
21	6.09	1.81	0.8	1.8
22	33.04	1.41	1.09	1.01
23	8.02	1.02	0.19	1.9
24	16.03	1.36	1.2	2.66
25	5.03	0.98	0.2	0.87
26	8.06	1.26	0.73	1.02
27	31.09	5.48	2.38	1.8
28	31.04	1.29	1.09	3.15
29	26.04	2.19	1.23	2.18
30	4.8	15.1	2.28	3.66
31	7.41	13.09	1.49	2.53
32	7.28	14.35	0.59	2.9
33	6.08	13.62	1.42	1.39
34	7.34	7.98	1.40	2.48
35	6.9	5.18	0.59	2.69
36	7.04	12.04	2.44	2.03
37	7.23	12.81	0.51	2.73
38	11.03	17.04	0.59	2.51
39	6.01	6.9	0.58	1.94
40	2.67	6.8	0.45	0.98
41	5.97	11.45	0.32	1.2
42	6.9	12.13	1.39	2.43
43	8.33	11.34	0.59	1.34
44	7.73	9.95	0.25	1.82
45	11.2	13.4	10.49	2.49
Mean	10.59	8.00	1.26	1.83

76°30'0.0"E

77°0'0.0"E

Available Zinc



19°30'0.0"N

19°30'0.0"N

19°0'0.0"N

19°0'0.0"N

Legend:-

Boundry

Soil sample

Available Zn (ppm)

Low (<0.6)

Medium (0.6-1.2)

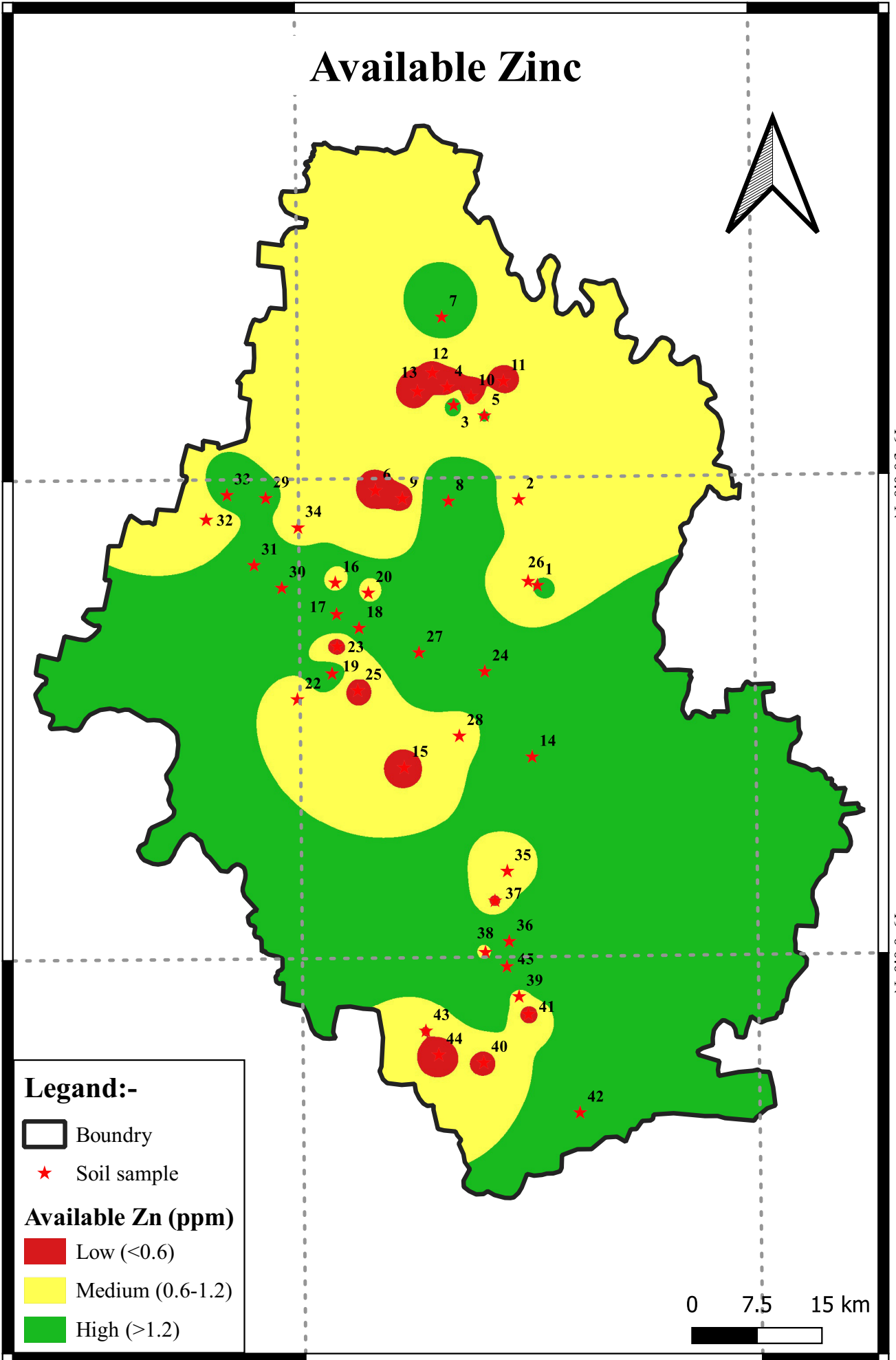
High (>1.2)

0 7.5 15 km



76°30'0.0"E

77°0'0.0"E



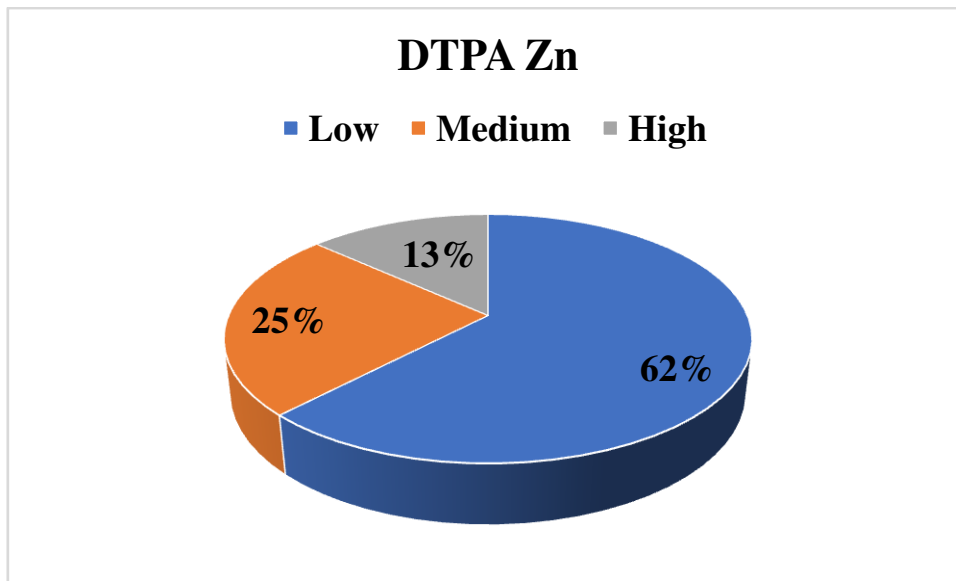


Fig. 4.16: DTPA Zn of surface soil of study area

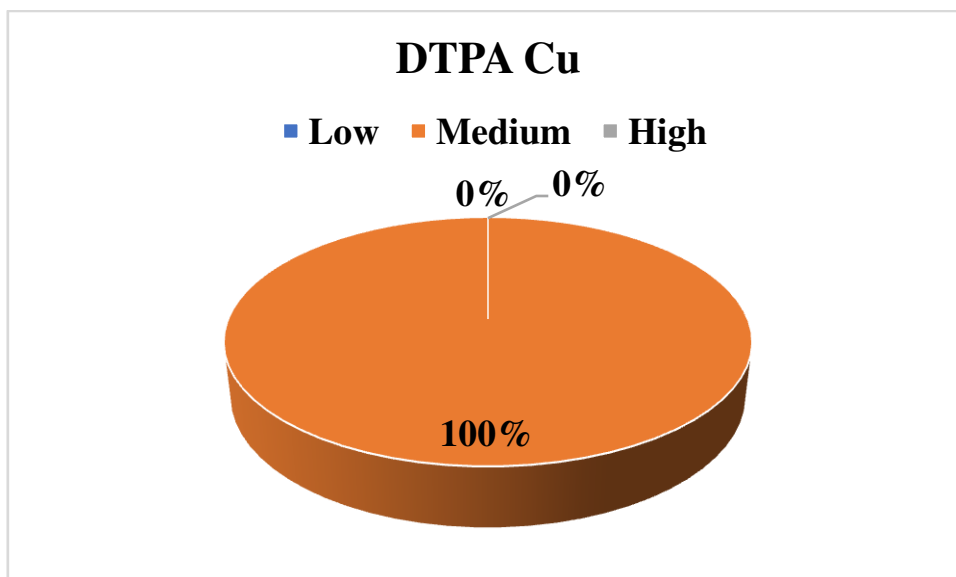
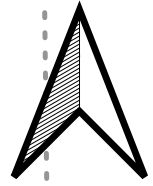


Fig. 4.17 DTPA Cu of surface soil of study area

76°30'0.0"E

77°0'0.0"E

Available Copper



19°30'0.0"N


19°30'0.0"N

19°0'0.0"N

19°0'0.0"N


Legend:-

 Boundry

 Soil sample

Available Cu (ppm)

 Low (<0.3)

 Medium (0.3-0.5)

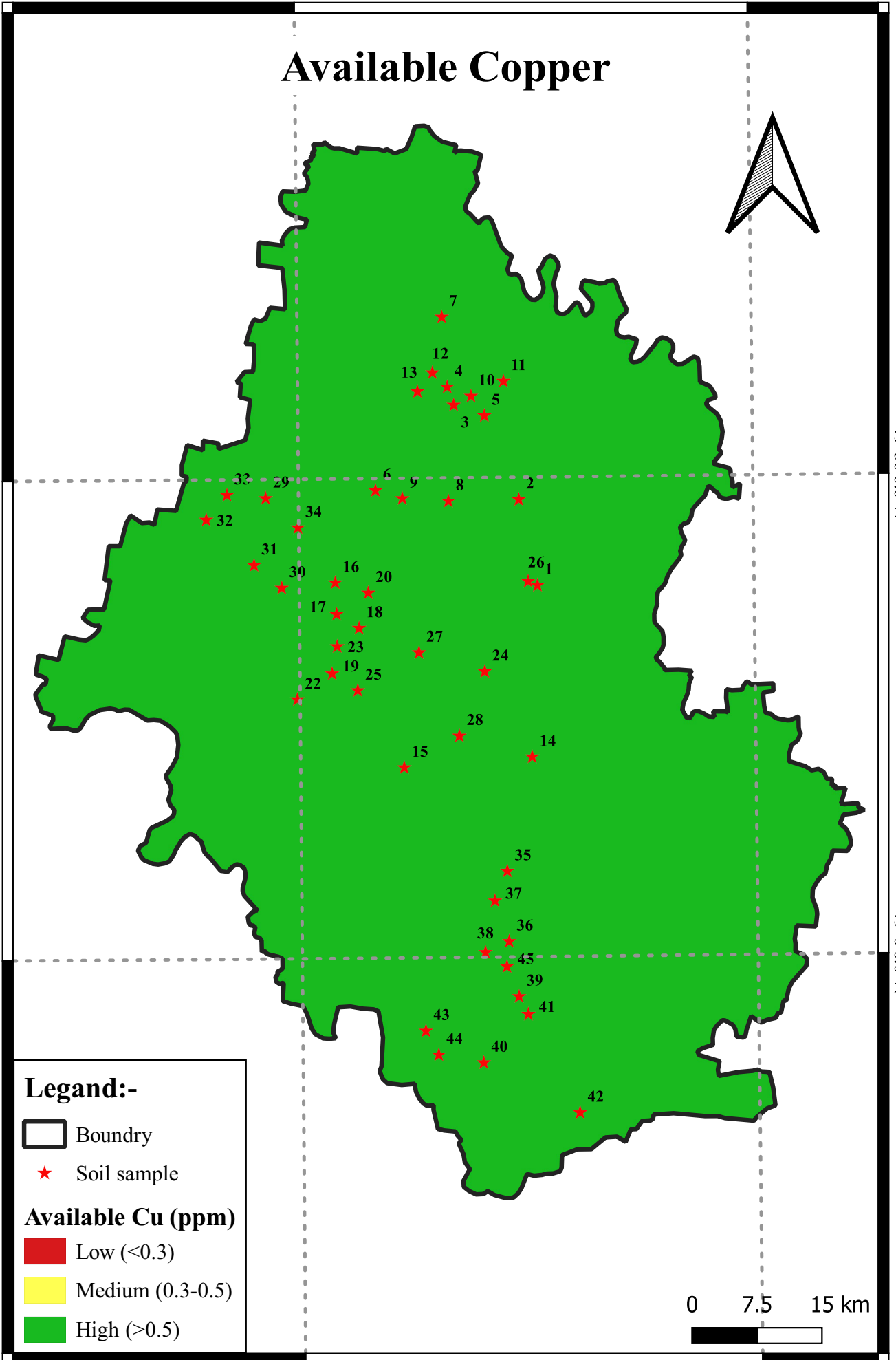
 High (>0.5)

0 7.5 15 km



76°30'0.0"E

77°0'0.0"E



4.7.3.4 DTPA Extractable Copper

The data on DTPA extractable copper content in surface soil samples collected from study area are given in Table 4.12, and found that, the DTPA Copper content in surface (0-30cm) soil samples were ranged from 0.87 to 4.89 mg kg⁻¹ with mean value of 1.83 mg kg⁻¹. The total 45 surface samples were collected from study area and out of these samples; all 45 (100%) soil samples were under medium range of categorization (Fig.4.17). The available copper content of cotton growing soils of Parbhani was moderate to high in nature. This is because of presence of chalcocite in the soil.

Table 4.15: Categorization of soils of study area on the basis of ratings of Fe, Mn, Cu and Zn

Soil Nutrient Status	No. of Soil Samples	NIV	Category
Iron (Fe)		2.97	High
Low	Nil		
Medium	1		
High	44		
Manganese (Mn)		2.62	High
Low	8		
Medium	1		
High	36		
Copper (Cu)		2.06	Medium
Low	Nil		
Medium	45		
High	Nil		
Zinc (Zn)		1.4	low
Low	28		
Medium	11		
High	6		

Mandavgade *et al.* (2015) observed that, the available copper in Jintur tehsil of Parbhani district was ranged between 0.75 to 6.54 mg kg⁻¹ with mean value of 2.55 mg kg⁻¹. Forty-five soil samples were analyzed and on the basis of nutrient

index, the soils were categorized in low, medium and high nutrient status of Fe, Mn, Cu and Zn respectively and it is presented in Table 4.14.

4.8 Correlation between soil physico-chemical properties and available nutrients in the cotton growing soil

The different soil properties are related with the availability of nutrients to the plants. Clay in the soil plays an important role in nutrient availability and cation exchange capacity. The soil pH is one of the important characteristics of soil which influenced on plant growth. Soil organic matter content in the soil is considered as the index of soil fertility and sustainability of crop.

Table 4.16: Correlation between the physico-chemical characteristics and available nutrients in the soil.

Title	pH	EC	OC	CaCO ₃
N	0.063	0.14	0.60*	0.047
P	-0.038	-0.09	-0.15	-0.009
K	0.63*	-0.02	-0.06	-0.55
Ca	0.09	0.23	0.07	-0.001
Mg	0.04	-0.21	-0.008	0.18
S	-0.26	-0.24	-0.04	-0.47
Fe	-0.17	0.23	-0.10	-0.22
Mn	-0.59	-0.25	0.08	-0.36
Cu	-0.44	0.19	-0.14	-0.23
Zn	-0.33	-0.28	-0.09	-0.28

* Significant at 5 % level ** Significant at 1 % level

4.8.1 Correlation between soil pH and available nutrients in the cotton growing soil

The data presented in Table 4.16 Showed that the soil pH was non-significant and negatively correlated with P (-0.038), S (-0.26), Fe (-0.17), Mn (0.59), Cu (-0.44) and Zn (-0.33) where as N, P, Ca and Mg were non-significant and positively correlated, except K has significant positive correlation with soil pH. The pH increased; the availability of micronutrient decreased. The similar results were obtained by Chavan (2020) and Singh *et al.* (2013)

4.8.2 Correlation between electrical conductivity and available nutrients in the cotton growing soil

The data revealed in Table 4.16 indicated that the electrical conductivity of soil was positively correlated with available Fe and Cu ($r = 0.23$), ($r = 0.19$) respectively. Similar correlations were observed by Chavan (2020). Also, EC indicated non-significant positively correlated with available nitrogen and calcium carbonate ($r=0.14$), ($r=0.07$) respectively. While negative correlations with available phosphorus ($r = - 0.094$) and potassium ($r = - 0.020$). Similar types of correlations were observed by Singh *et al.* (2013).

4.8.3 Correlation between organic carbon and available nutrients in the cotton growing soil

The Table 4.16 stated that the correlation of cotton growing soils of Parbhani district, and data showed the organic carbon was significantly positive correlation with available nitrogen ($r = 0.60$). While non significant correlation available P, K, S, Fe, Zn and Cu ($r = -0.15$), ($r = -0.06$), ($r = -0.04$), ($r = -0.10$), ($r = -0.09$) and ($r = -0.14$) respectively. The similar results were found by Singh *et al.* (2013). The organic carbon content of soil increased with the availability of nutrients in the soil.

4.8.4 Correlation between calcium carbonate and available nutrients in the cotton growing soil

The Table 4.16, showed that the calcium carbonate was non-significant positively correlated with available nitrogen ($r = 0.04$). Similar results were found by Waikar *et al.* (2014). The calcium carbonate showed non-significant negative correlation with available Cu, available Zn and available Mn ($r=-0.36$) and ($r=-0.23$) respectively. This indicated that, the calcium carbonate increased, the availability of other nutrients decreased. Similar results was reported by Ghode (2018) also Chadar (2018).

4.9 Yield of cotton

Yield is an important factor of any crop and the changes in yield occur because of different aspects like soil type, management practices of crop and soil

selection, varieties and climatic factors like arid region, humid region etc. In the cotton growing area of Parbhani district, it has been observed a vast change in soil types and yield ratio of cotton. The yield data of cotton collected under similar management practices from study area of soil profile and surface samples indicated that the yield of cotton varied from 8.5 to 18.5 q ha⁻¹ and maximum yield of cotton (18.5 q ha⁻¹) was obtained at Calcic Haplusterts (P₃) followed by Calcic Haplustepts (13 to 18.5 q ha⁻¹). The cotton yield was highly significant positive correlated in Table 4.6 with clay, PAWC and CEC (r= 0.95, r= 0.94 and r= 0.96 respectively). This is clearly indicated that the yield of cotton is depending upon soil type and soil qualities.viz CEC, PWAC and depth of soil.

4.9.1 Correlation of physical properties with yield of cotton

Data raveled in Table 4.17 showed that the yield of cotton was significantly positive correlation with Plant available water capacity (PWAC) (r=0.9751*) soil depth (r = 0.99), Clay r = 0.99) and CEC r = 0.97). (Fig 4.18, 4.19, 4.20, 4.21).

Table 4.17: Correlation coefficients between soil attributes and yield of cotton.

Crop	Parameter X	Parameter Y	r value
Cotton	Depth (cm)	PAWC (mm)	0.9798*
	Clay (%)	CEC cmol (p ⁺) kg ⁻¹	0.9863*
	Clay (%)	PAWC (mm)	0.9813*
	Depth (cm)	Yield (kg ha ⁻¹)	0.9948**
	Clay (%)	Yield (kg ha ⁻¹)	0.9995**
	PAWC (mm)	Yield (kg ha ⁻¹)	0.9751**
	OC (%)	Yield (kg ha ⁻¹)	0.9544
	CaCO ₃ (%)	Yield (kg ha ⁻¹)	-0.9537
	CEC cmol (p ⁺) kg ⁻¹	Yield (kg ha ⁻¹)	0.9663*

*Significant at 5% ** Significant at 1%

It is suggested that the soil depth, CEC, PWAC and Clay content are the yield dependent factors. Similar results were found by Patil *et al.* (2013) and reported that the significant positive correlation of soil depth with PAWC (r=0.908)

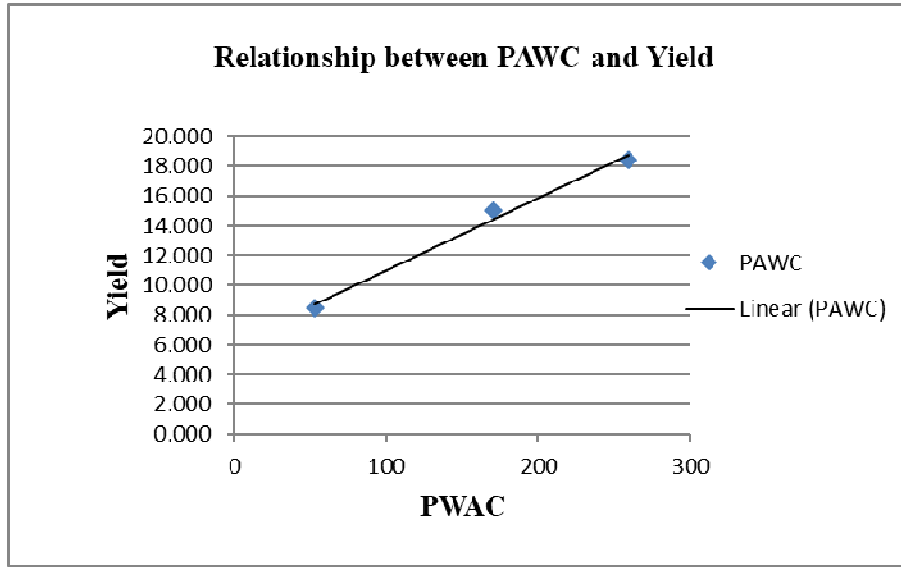


Fig .4.18 Relationship between PWAC and Yield

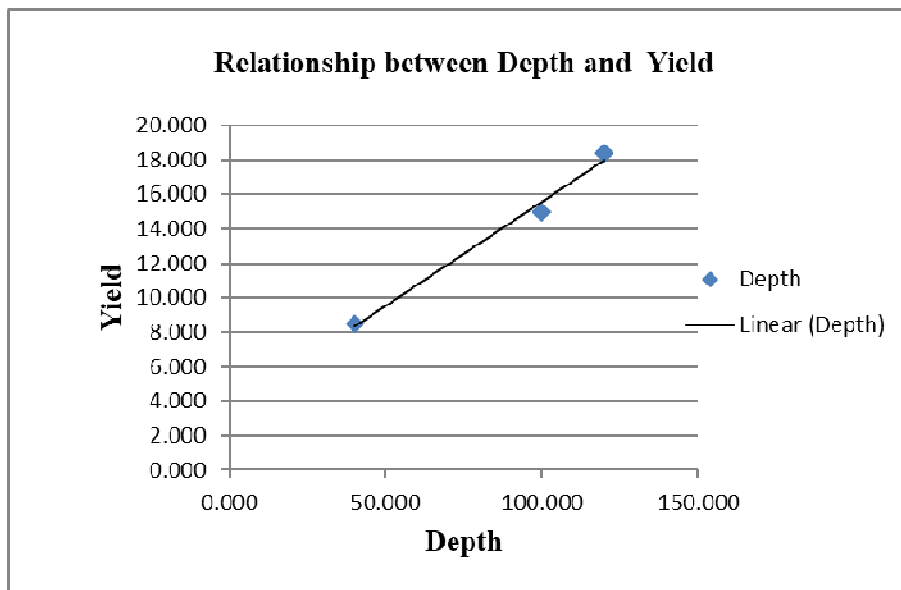


Fig .4.19 Relationship between Depth and Yield

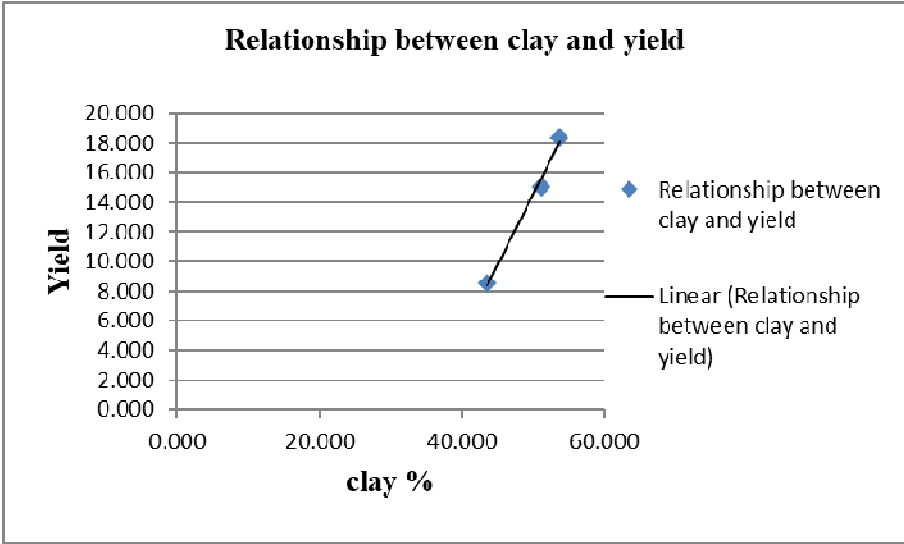


Fig .4.20 Relationship between Clay and Yield

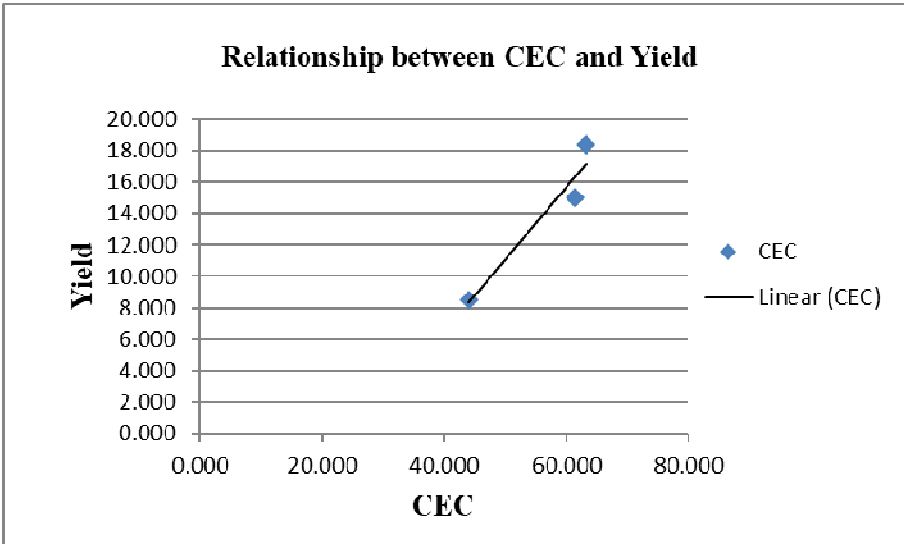


Fig .4.21 Relationship between CEC and Yield

and this revealed that the soil depth, texture and PAWC are interrelated to each other and ultimately influenced on crop yield. They also found that CEC of soil influencing on yield of crop and it had positive correlation of CEC and yield of soybean ($r=0.751$) and pigeon pea ($r=0.759$).

4.10 Soil Nutrient Index Value

The data on nutrient index values of soils of cotton growing in Parbhani were presented in Table 4.18. Considering the concept of nutrient index values, the soil pH, EC, organic carbon and CaCO_3 in soils of Parbhani district were categorized as alkaline, safe, low and calcareous in nature, respectively. The available N and P were low, while available K, exchangeable Ca^{++} and Mg^{++} , Fe, Mn and Cu were high. The nutrient index values for pH, EC, organic carbon and CaCO_3 were 2.91, 1.02, 1.28 and 2.13, respectively. The NIV of available N, P and K were 1.15, 1.8 and 2.97, respectively and for Ca^{++} , Mg^{++} and S were 3, 3 and 2.48 respectively. The nutrient index values of Fe, Mn, were high while Cu and Zn were 2.97, 2.62, 2.06 and 1.6 respectively. With the help of these values the soils of Parbhani district were categorized.

The data on nutrient index values revealed that all the soils collected from surveyed area of Parbhani District were characterized as, pH was alkaline, EC was safe, organic carbon was low and soils were calcareous in nature. These soils were low in N thus soils of this region are expected to respond to the added N. P containing fertilizers are to be the greater magnitude. The lower content of available nitrogen in this region is associated with hot and dry climate complex, low content of organic matter and total N reserve and in tane C; N ratio nitrogen. Malewar *et al.*,(1998) reported N deficiency in soils of northern Marathwada. The investigated soils, however rated as low in available phosphorous because of continuous mining by the crops from soils and higher amount of CaCO_3 in these soils which get fix the native and applied phosphorous in soil. On the other hand, most of the soils were rated as higher in available potassium. The high content of available potassium in soils mainly associated with the presence of K rich mineral in Vertisols and associated black soils. However, exchangeable Ca^{++} and Mg^{++} were rated as high fertility index value. Further, DTPA-Fe and Mn in these soils were high whereas Cu and Zn found medium in nature (Fig.4.22).

Table 4.18: Soil nutrient index values

Sr. No.	Available nutrients	NIV	Category
1	pH	2.8	High
2	EC (dsm ⁻¹)	1	low
3	Organic Carbon	1.17	low
4	CaCO ₃	2.3	High
5	Available N	1.15	low
6	Available P	1.8	Low
7	Available K	2.97	High
8	Exchangeable Ca ⁺⁺	3	High
9	Exchangeable Mg ⁺⁺	3	High
10	Available S	2.48	Medium
11	DTPA- Fe	2.97	High
12	DTPA- Mn	2.62	High
13	DTPA-Cu	2.06	Medium
14	DTPA- Zn	1.6	Medium

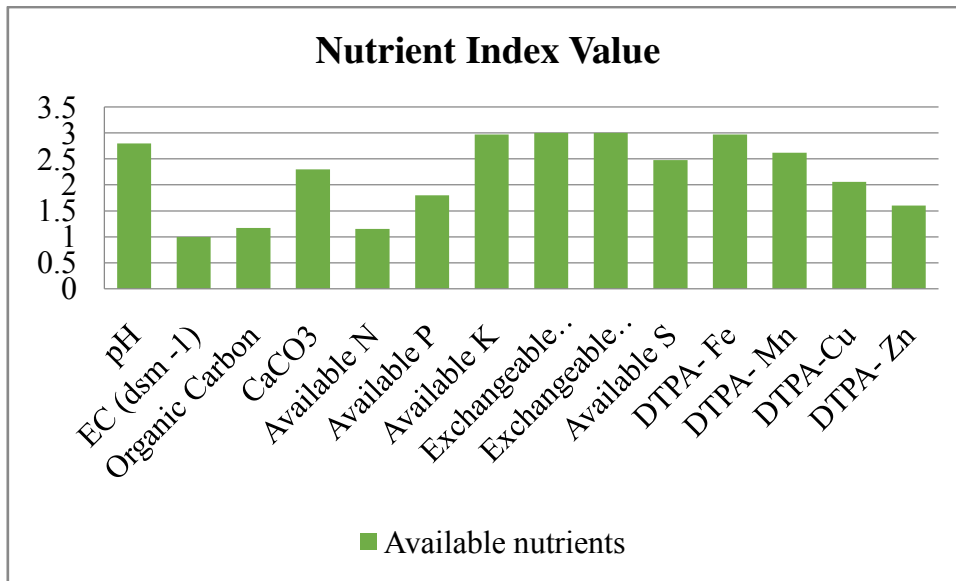


Fig. 4.22 Nutrient index of soils of study area

Nutrient Index Values:

In order to compare the levels of soil fertility of one area with those of another. It was necessary to obtain a single value for each nutrient. Nutrient index value is a measure of nutrient supplying capacity of soil to plants. Soil nutrient index was calculated for low, medium and high rating of soil nutrients. If nutrient index value is less than 1.67, the fertility status is low and the values between 1.67- 2.33 and status is medium. If the values greater than 2.33, the fertility status is high.

Parker's nutrient index is a three tier system used to evaluate the fertility status of soils based on the percentage of samples in each of the three classes that is low, medium and high.

Formula for calculation of Nutrient Index Value (NIV):

$$NIV = \frac{N_L + 2 * N_M + 3 * N_H}{N_L + N_M + N_H}$$

(N_L = low nutrient index, N_M = Medium nutrient index, N_H = High nutrient index)

CHAPTER – V

SUMMARY AND CONCLUSION

CHAPTER -V

SUMMARY AND CONCLUSION

In the present investigation entitled “Evaluation of Soil quality under cotton growing soils of Parbhani District” was aimed to categorize and classify of soils of Parbhani district and is located in Maharashtra between 18° 45” to 20° 10” N latitude and 76° 13” to 77° 39” E longitude. The geographical area of Parbhani is 6511 sq. km. The climate of the area is hot, dry and sub humid with annual rainfall of 1089 mm. The mean maximum and minimum temperature are 33.06 °C and 26.03 °C respectively. Three (03) representative pedon from different physiographic unit of characterized and classified. The forty-five (45) surface soil samples (0-30cm) from different land use area of adjoining soil profile by G.P.S based survey samples were collected for laboratory soil analysis.

Soil depth of the study area varied from 30 to 100+ cm which corresponds to shallow to very deep, soil colour of study area was very dark gray (10 YR 3/1) to dark brown (10YR 3/4) in colour. Soil structure is varying from granular to angular blocky. In Calcic Haplusterts, the soil’s structure varied from medium, strong, angular blocky to medium, weak, sub-angular blocky. Calcic Haplustepts soils are medium, weak, sub-angular blocky to medium, strong, sub-angular blocky. in structure. The soils were clay loamy to clay in texture and soils consistency varies from soft in dry condition, friable in moist condition, non-sticky non-plastic in wet condition and hard in dry condition. The coarse fragment of soils varied from 3 to 40.41 per cent.

The bulk density of cotton growing soils of Parbhani district varied from 1.48 to 1.79 Mg m⁻³. The saturated hydraulic conductivity of the soils varied from 4.38 to 14.43 cm hr⁻¹. Soils are clay loam to clay in texture and clay per cent ranged from 30.4 to 47 per cent. It was found that this variation attributed to textural difference. The plant available water capacity of soils varied from 53.06 to 258.85 mm.

The pH of soil was varied from 7.5 to 8.4 with mean value of 7.9 pH. The salt concentration in these soils ranged from 0.16 to 0.32 dSm⁻¹ with mean value of 0.22 dSm⁻¹. Soils were found in safe limit (less than 1 dsm⁻¹) of electrical conductivity and categorized as safe in salt concentration and increased with

increase in depth of soil. The organic carbon status in soil was low to moderate and ranged from 0.1 to 0.5 per cent; free calcium carbonate content in soil profile samples was ranged from 7.8 to 28.4 per cent. It was found that the calcium carbonate increased with increasing depth of soils.

The CEC of soil varied from 37.2 to 66.18 $\text{cmol (p}^+) \text{ kg}^{-1}$. The high CEC is attributed to the high amount of clay. The exchangeable cation in soils has the dominance of calcium followed by magnesium, sodium and potassium in all profiles. The base saturation per cent varied from 94.94 to 98.53 per cent. The high base saturation of both soil and murrum was attributed to basaltic parent material which is basic in nature.

Correlation study showed that the CEC positively correlated with clay ($r=0.98^*$) and there by increased with increasing clay content in soil. The depth of soil is significant positively correlated with PAWC ($r = 0.97^*$) and significant positively correlated with clay ($r=0.98^*$). The PAWC increases with the increases in depth of soil.

The soils of the study area are classified according to U.S. comprehensive system of soil classification (Soil Survey Staff 2006 and 2015). The soil of the study area belongs to two orders viz, Inceptisals and Vertisols and at subgroup level these soils classified as Calcic Haplustepts and Calcic Haplusterts.

Surface soil samples (0-30 cm) were studied and indicated that these soils were slightly to moderately alkaline in reaction (7.30 to 8.54). The electrical conductivity of soils varied from 0.21 to 0.68 dsm^{-1} with mean value 0.41 dsm^{-1} . The organic carbon content of soils was low to medium and varied from 0.21 to 0.58 per cent and 82 per cent soil samples was deficient in organic carbon. Calcium carbonate content of soil ranged from 5.09 to 14.50 per cent with the mean value 9.79 per cent. The 85 per cent soil samples of cotton growing areas of Parbhani district was found calcareous in nature.

The soils of study area were low in available nitrogen content and ranged from 106.6 to 304.60 kg ha^{-1} with a mean of 199.14 kg ha^{-1} . About 79 per cent samples found in low and 15 per cent sample found in medium and 6 per cent sample found high in available nitrogen

The soil of study area, were low to medium in available phosphorus content and ranged from 7.90 to 22.30 kg ha^{-1} with a mean value 13.09 kg ha^{-1} . About 11 per cent samples were belongs to low and 89 per cent samples belongs to medium,

while 11 per cent soil samples are deficient in available phosphorus. The available potassium content in soils varied from 263.6 to 898 kg ha⁻¹ with an average value of 565.7 kg ha⁻¹. The 11 per cent soil samples were high and 89 per cent samples were in very high range.

All the soil samples were high in exchangeable Ca and Mg content and varied from 29.04 to 33.66 mg kg⁻¹ and 15.84 to 25.74 mg kg⁻¹ respectively. The available S content ranged from 6.08 to 14.91 mg kg⁻¹ and correspond to 51 per cent samples were low to deficient in available sulphur and 49 per cent samples was found in medium range.

The DTPA extractable micronutrients i.e., Fe, Mn, Zn and Cu varied from 2.67 to 31.09, 0.98 to 17.04, 0.19 to 10.49 and 0.87 to 4.89 mg kg⁻¹ respectively. The 97 per cent soil samples were found high in Fe, 80 per cent soil was found high in Mn, low to high in DTPA- Zn, 63 per cent samples qualify for low, 24 per cent qualify for medium and remaining 13 per cent qualify for high category. The Cu content in soil, 100 per cent soil samples of study area found to be medium. The DTPA extractable micronutrients in soils were high in Fe followed by Mn, Cu and Zn. The 2 per cent soil samples are deficient in DTPA Mn and 63 per cent were deficient in DTPA Zn.

Correlation study showed that, there was significantly positive relationship of organic carbon with nitrogen while negatively non-significant correlation with P, K, Mg, S, Fe, Zn and Cu ($r = -0.15$), ($r = -0.06$), ($r = -0.008$), ($r = -0.04$), ($r = -0.10$), ($r = -0.14$) and ($r = -0.09$) respectively. The pH showed significant positive relationship with K ($r = 0.63^*$) and CaCO₃ showed non-significant negative relationship with all macro and micro nutrients except Mg⁺⁺ and N ($r = 0.18$) and ($r = 0.047$), this may be because of different types of soil and clay content.

However, concluded that, the cotton growing soils of Parbhani district, soils were shallow to very deep, very dark gray to dark brown in colour and clayey in nature and Taxonomical classified as Calcic Haplustepts and Calcic Haplusterts. NIV was found low in N, P and OC; medium in S, Cu and Zn where as to high in K, Ca, Mg, Fe and Mn. Correlation study showed that, there was significantly positive relationship with soil depth, clay content, CEC, PAWC, and negative with CaCO_3 indicating the these are yield reducing factors for cultivation of cotton in Parbhani district. It needs to adopt the conservation agriculture practices for improvement of PAWC in low clay content soil and application of organic manures for reduce the adverse effect of CaCO_3 and increased the availability of nutrients.

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APPENDIX

APPENDIX - I

Rating chart of EC, CaCO₃, Ca⁺⁺, Mg⁺⁺, Available Sulphur DTPA Fe, Mn, Zn and Cu by Three tier system.

Soil Property	Unit	Range		
		Low	Medium	High
Electrical Conductivity	dsm ⁻¹	< 1.0 (Normal)	1.0 – 2.0 (Critical)	> 2.0 (Injurious)
Calcium Carbonate	%	< 5 (Low)	5 – 10 (Medium)	> 10 (High)
Exchangeable Calcium (Ca ⁺⁺)	cmol (p ⁺) kg ⁻¹	<0.1 (Low)	0.1 – 1.0 (Medium)	>1 (High)
Exchangeable Magnesium (Mg ⁺⁺)	cmol (p ⁺) kg ⁻¹	< 0.04 (Low)	0.04- 0.33 (Medium)	> 0.33 (High)
Available Sulphur	Mg kg ⁻¹	< 5 (Low)	5 – 10 (Medium)	> 10 (High)

(Somawanshi *et al.* 2012)

Soil Property	Unit	Range		
		Low	Medium	High
DTPA Fe	Mg kg ⁻¹	< 2.5 (Low)	2.5 – 4.5 (Medium)	> 4.5 (High)
DTPA Mn	Mg kg ⁻¹	< 2 (Low)	2– 5 (Medium)	> 5 (High)
DTPA Zn	Mg kg ⁻¹	< 0.60 (Low)	0.60 – 1.20 (Medium)	> 1.20 (High)
DTPA Cu	Mg kg ⁻¹	< 0.30 (Low)	0.3– 0.5(Medium)	> 0.5 High)

(Jones 1980)

APPENDIX – II

Rating chart of Available N, P, K and Organic Carbon by Three tier system.

Soil Property	Unit	Range		
		Low	Medium	High
Available Nitrogrn	Kg ha ⁻¹	< 280 (Low)	280 -560 (Medium)	> 560 (High)
Available Phosphorus	Kg ha ⁻¹	< 10 (Low)	10– 25 (Medium)	> 25 (High)
Available Pottasium	Kg ha ⁻¹	< 120 (Low)	120 – 280 (Medium)	> 280 (High)
Organic Carbon	%	< 0.5 (Low)	0.5– 0.75 (Medium)	> 0.75 (High)

(ISSS, 2012)

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Place: Parbhani

Date: 30/8/2021


(Sule Sagar Malhari)