# Characterization and Classification of Soils of Experimental Area of Department of Soil Science

**BY**

**Tamanna Saroha**

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***Thesis submitted to Chaudhary Charan Singh Haryana Agricultural University, Hisar in partial fulfilment of theRequirements for the degree of***

## MASTER OF SCIENCE

## IN

## SOIL SCIENCE

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## CERTIFICATE–I

This is to certify that this thesis entitled "**Characterization and Classification of Soils of Experimental Area of Department of Soil Science**" submitted for the degree of **Master of Science** in the subject of **Soil Science** of the Chaudhary Charan Singh Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Ms. Tamanna Saroha**, **Admission Number 2019A132M** under my supervision and that no part of the thesis has been submitted by him for any other degree.

All the assistance and help received during the course of investigation have been duly acknowledged.

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## CERTIFICATE–II

This is to certify that this thesis entitled "Characterization and Classification of Soils of Experimental Area of Department of Soil Science" submitted by **Ms. Tamanna Saroha**, **Admission Number 2019A132M** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar in partial fulfilment of the requirement for the degree of **Master of Science** in the subject of **Soil science**, has been approved by the Student's Advisory Committee after an oral examination on the same.

**MAJOR ADVISOR** **EXTERNAL EXAMINER**

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## ABBREVIATIONS USED

| | |
|---|---|
| AICRP | All India Coordinated Research Project |
| BD | Bulk Density |
| CEC | Cation exchange capacity |
| DTPA | Diethylene Triamine Penta Acetic Acid |
| EDTA | Ethylene diamine tetra acetic acid |
| ESP | Exchangeable sodium percentage |
| *et al.* | and others |
| FAO | Food and Agricultural Organisation |
| FYM | Farm Yard Manure |
| ISSS | Indian Society of Soil Science Society |
| IWMP | Integrated Watershed Management Programme |
| LCC | Land Capability Classification |
| LUP | Land Use Planning |
| MSL | Mean Sea Level |
| PD | Particle Density |
| PS | Pore space |
| RSC | Residual sodium carbonate |
| SAR | Sodium adsorption ratio |
| SP | Saturation Percentage |
| USDA | United States Department of Agriculture |
| WRB | World Reference Base |

## SYMBOLS USED

| | |
|---|---|
| % | Percentage |
| $^{o}$ | Degree |
| Fig. | Figure |
| EC | Electrical conductivity |
| M C | Moisture content |
| BSP | Base saturation percentage |
| $dS\ m^{-1}$ | Deci Siemens per metre |
| $cmol\ (p^{+})\ kg^{-1}$ | Centimole per kilogram |
| $mg\ kg^{-1}$ | milligrams per kilogram |
| $Kg\ ha^{-1}$ | Kilogram per hectare |
| $Mg\ m^{-3}$ | Mega gram per cubic meter |
| ppm | parts per million |
| $K^{+}$ | Potassium |
| $Ca^{2+}$ | Calcium |
| $Na^{+}$ | Sodium |
| $Mg^{2+}$ | Magnesium |
| $NO_3^{-}$ | Nitrate |
| N | Nitrogen |
| P | Phosphorous |
| K | Potassium |
| pH | Negative logarithm of $H^{+}$ ion concentration |
| NaOH | Sodium Hydroxide |
| $NaHCO_3$ | Sodium bicarbonate |
| $CaCO_3$ | Calcium Carbonate |
| OC | Organic carbon |
| $EC_e$ | Electrical Conductivity of Saturation extract of soil |
| Mha | Million hectares |
| Zn | Zinc |
| Fe | Iron |
| Mn | Manganese |
| Cu | Copper |
| MPa | Mega Pascal |

## CHAPTER-I

## INTRODUCTION

Among the natural resources soil holds the central place needed for the development and growth of any country. Soil is a natural body made up of solids (minerals and organic matter), liquids and gases that exists on the land surface takes up space and has one or both of the following characteristics: Horizons or layers, that are distinguishable from the initial material as a result of energy and matter additions, losses, transfers and transformations or the ability to sustain rooted plants in a natural environment. Many factors influence soil variations, according to Rajgopal *et al*., (2013), including the quality of soil parent materials, environment and weathering patterns over time. The combination of soil characterization and classification offers useful knowledge and understanding of the physical, chemical, mineralogical and biological properties of soils, which helps precision agriculture by reducing the negative effects of soil diversity (Sharu *et al*., 2013; Ukut *et al*., 2014).

The relationships between soil properties in a specific landform may help determine the dominant pedogenic processes of these soils and provide an opportunity to manage them better and improve crop performance. Therefore, there is need to understand the interactions between soil properties influenced by dominant pedogenic processes and their effect on crop yield in the study area.

The site specificity of agricultural research and technology results is largely measured from differences in two environmental variables: soil and climate. A general evaluation, based on limitations of land characteristics, is best illustrated in the USDA land capability classification. The classification points out automatically the possibilities and limitations of the climate for each crop and type of agriculture. In India, the land resources available for agriculture are shrinking. Our aim of optimizing the utilization of land resources with intensification of agriculture resulted either in the fast depletion of nutrients or occasionally in their accumulation. It is, therefore, important to monitor the fertility status of soil from time to time with a view to monitor the soil health. There is an overwhelming need to manage and conserve the natural resource base with adoption of appropriate technologies that are economically viable, socially acceptable and environmentally non-degrading in all aspects. Scientific management of soil will help in conservation of valuable natural resources and yield high output per unit of input applied along with sustainable use (Singh and Rathore, 2017).

Soil characterization offers knowledge on the physical, chemical, mineralogical and microbiological properties of soils allowing us to better understand them andadvise to both existing and potential land users for the best possible way of land resourses (Devi et al., 2015). Based on comprehensive knowledge about soil properties, characterization of watershed areas may be used to assess soil limitations and potentials (Khan and Kamalakar, 2012). According to Yadav (2003), India's per capita cultivable land is declining and is unlikely increasing in a horizontal direction. The task is not only to feed an ever-increasing population, but also to sustain the soil resource's productivity for future generations.

Understanding the dynamics and distribution of the soil characteristics as influenced by landscape features is critical for assessing the effect of future land use and management (Kosmas *et al.*, 2000). Sustainable management practices that are based on understanding of the soil systems are not available for most parts of the state.Degrading soil fertility, improper land use, shrinking agricultural acreage, and illogical input utilisation were previously ignored, but academics are increasingly paying attention to this issue (Kanwar, 2004). Based on profile wise information, soil management practices specific to that region can be recommended to the researchers and other stakeholders for its judicious use (Kumar and Prasad, 2010). Consequently, this will lead to sustainable agriculture along with environmental protection

Land is the greatest source of wealth and the backbone of many great civilizations. Inefficient land use would eventually result in permanent deterioration and irreversible environmental damage. Deteriorating soil fertility can be a major challenge to countries like India, where agriculture accounts for a large portion of the economy. The past soil survey activities are mainly conducted at regional and small-scale, which are inadequate in providing basic soil data that can help to manage soils according to the local variability. Therefore, the present study was carried out with the following objectives:

- To characterize the morphological, physical and chemical properties of soils
- To classify and map the soils of Experimental Area of Department of Soil Science, CCSHAU, Hisar

# CHAPTER-II

## REVIEW OF LITERATURE

The rational utilization, improvement and conservation of soil resources are impossible without broadening thorough understanding of their morphological, physio-chemical properties andtheir characterisation and classification. An intimate knowledge on their characteristics, classification, location, extent and distribution, potentials and problems is a prerequisite for developing rational land use and sustainable planning. Land use planning is the systematic assessment of physical, social and economic factors in such a way as to encourage and assist land users in choosing options that increase their productivity, sustainability and meet the needs of society (FAO 1993). Although the soils of much of the semi-arid regions are superficially similar in appearance, careful study reveals a great diversity. The literature pertaining to the present investigation has been reviewed under following major headings:

2.1 Morphological characteristics

2.2 Physical characteristics

2.3 Chemical characteristics

2.4 Soil classification

### 2.1 Morphological characteristics

Various soil formation elements influence morphological characteristics such as colour, texture, horizon border, consistency, and structure. Various workers assigned different morphological qualities to soil in order to study soil morphology, but colour was regarded to be a significant morphological property that is the result of a variety of variables.

The soils of Vadamalalpeta Mandal in Chittoor district were described by Kumar and Naidu (2012) as moderately deep to extremely deep and imperfect to well drained. The lowlands had reddish yellow (7.5 YR6/8) to yellowish brown (10 YR5/4) soils, whereas the uplands had yellowish red (5 YR4/6) to dark red (2.5 YR3/6) soils.

The soils were loose, single grained, or weekly evolved sub-angular blocky, according to Ahuja et al.(1997), who noticed variance in soil properties in the sand Dunal area of Haryana, taking into account the geographic sequence. The sand dune's sub-angular blocky soils were weak.

Tripathi *et al. (*2006) assessed the soils of the Kiar-Nagali micro-watershed in the northwestern Himalayas, describing the surface horizons as dark brown (10 YR3/3) to yellowish brown (10 YR5/4) and the subsurface horizons as brown (10 YR4/3) to dark yellowish brown (10 YR4/4) in colour. The existence of substantial organic matter content in these soils could account for the black matrix colour.

The plains' soils were very deep and badly drained, according to Walia and Rao (1997), whereas the Shiwalik hills and valleys' soils were moderately deep to shallow and well drained. Soil colour can be influenced by moisture regime and topographic situation, as well as chemical and mineralogical composition and textural make-up. In terms of distinctness and smoothness, the horizon margins were wavy in topography and abrupt, clear, progressive, and dispersed.

The precise knowledge of soil texture is critical in the study of soil morphology, classification, mapping, and genesis. Rao *et al*. (2008) discovered that soil texture varies widely depending to the kind of parent material, topographic situation, in situ weathering, clay translocation, and soil age.

Sahoo et al. (2020) found Fe and Mn concretions in lower horizons of soils in selected watershed area of Haryana, North-west India andobserved that poorly drained soils have greater concretions than well-drained soils.$CaCO_3$ concentration ranging from 0.85 to 1.83 g $kg^{-1}$(plains), 0.53 to 1.40 g $kg^{-1}$ (uplands), and 0.50 to 0.85 g $kg^{-1}$(hills) in the Chittoor district of Andhra Pradesh, according to Rao *et al*. (2008). In comparison to surface horizons, subsurface horizons have a greater $CaCO_3$ content.

Swarnam *et al*. (2004) found that the Shahibi basin soils in Delhi and Haryana were shallow to deep (5 to 60 cm), dark red to dark greyish brown (2.5 YR 3/6 – 10 YR3/2), and well drained. The findings revealed that soil property differences had a significant impact on landform and topography.

Karmakar *et al*. (2014) investigated the soils in Assam's North Bank Plain Zone for distinct morphological features and found substantial variances with a prevailing hue of 10 YR. Aquic features show a chroma of 2 in soils from alluvial and flood plains.

The soils in the Hirna watershed were characterised by Gebrekidan and Mishra (2005), who found that the soils on steep slopes were shallow, while the soils on topographic low points were deep. The soils on the rear slopes of mountains were gravelly and degraded quickly, especially on steep slopes. When the soil was moistened, the colour often turned to a reddish hue.

Dinesh *et al. (*2017) investigated the soils of diverse geomorphic units in north-eastern Haryana, showing that the soils were mostly moderate to strongly alkaline(7.8-9.4), with the exception of a rare low-pH pedons in the Shiwalik hills (6-7.35). Organic carbon was less than 1% except in the top strata of forest habitats. The unequal distribution of calcium carbonate detected in a few pedons was caused by the riparian nature of soils.

While characterising the soils of the Chandan river system, Pandey and Kumar (2015) discovered that the upland physiographies of old alluvial soils under direct impact of the river Chandan had yellowish brown colour.

Sahu *et al*. (2001) investigated the morphological characteristics of four Vertisol pedons in Orissa's Western Zone, finding that the soils were very deep, the soil colour ranged from black to greyish brown in different horizons, crevices of 2 to 3 cm wide that extended beyond 1 m, slickensides, wedge shaped aggregates, iron, manganese, and concretes in the subsurface horizons of the soils, and slicken.

According to Challa *et al*. (2000), the piedmont plains soil of Kadambhe and Khondwad in Maharastra being dark greyish brown; while the flood plain soils of Valpi and Amalner were dark yellowish brown.

When Rudramurthy and Dasog (2001) investigated the features and origins of red and black soils in North Karnataka, they discovered that red soils had a redder colour, higher chroma, and more coarse particles. On the other hand, black soils had a yellower tint, lower chroma, and fewer coarse pieces.

**2.2 Physical characteristics**

Texture is the most important of the different physical features of soils that affect the moisture suction connection, and it should be considered the most basic property that can change the soil water relationship.

Swarnam *et al.* (2004) studied the soils of the Shahibi basin within Delhi and Haryana and discovered that the texture ranged from sandy loam to sandy clay loam, with physiographic variance. Clay percentage and infiltration rate were higher in the midland and lowland soils. The bulk density, particle density, and water retention capacity of highland soils were all higher.

According to Bandyopadhyay *et al*. (2014), some tea-growing soils in Jorhat's fairly gently sloping plains (P1 and P2) are very deep, well drained, and contain brownish-yellow to yellowish-brown matrix, loamy A horizons to clay-loam argillic B horizons. Soils on nearly level plains were moderately (P3) to imperfectly (P4) drained, with dark yellowish brown to yellowish brown, sandy loam to loam A horizons and yellowish brown to light yellowish brown or brownish yellow matrix in B horizons with sandy loam to sandy clay loam textures and an aluminium saturation of 48 (P1) to 63 percent (P3). In the soil control section, the strongly acid subsoil (P4) have a brown to yellowish brown matrix with sandy loam to loam texture and a base saturation of more than 35 percent.

Dinesh *et al.* (2017) investigated the soils of various geomorphic units in north-eastern Haryana, finding that bulk density ranged from 1.15 to 1.62 Mg $m^3$ and did not indicate any regular pattern with depth, with the exception of pedons 7 and 9 of the Shiwalik hills-valley and pedons 15, 16, and 17 (flood plains), which exhibit an increasing pattern along depth due to progressive compaction caused by eluvial materials filling pores, decreased organic matter, and less aggregation. It was discovered that the texture ranged from light to moderately heavy. The soils do have sub angular blocky structure that is weak to medium. Because the sediments were younger and there was a lot of rain, there were no calcium carbonate nodules.

When Pandey and Kumar (2014) studied the soils of the Chandan river system, they discovered that the upland physiography of old alluvial soils underneath the direct influence of the river Chandan was characterized by sandy loam to sandy clay loam in texture, as well as very slow to slow hydraulic conductivity.

According to Ahuja *et al*. (1997), the soils of the dunal plain areas were far more pedogenically developed, as demonstrated by the illuviation and calcification processes, but soils on other dunal topographic sites were either devoid of pedogenic activity or had weak pedogenic activity.

Pulakeshi *et al*. (2014) studied the soil resources from Mantagani village in Karnataka's northern transitioning agro-climatic zone (zone-8) and found that the soils are silty clay, clay, and silt clay loam.

Kuhad *et al. (*1975) found that the physiography of the area, as well as the texture of distinct horizons in the soil profile, largely regulated the moisture retention and storage capacity of soil in Haryana, and also that fine loamy classes retained more accessible moisture than coarse loamy classes.

The texture of soils in the Abobo area of western Ethiopia was clay loam to clayey, with bulk density values varying from 1.12 to 1.32 g cm3 and basic infiltration rates ranging from poor to moderate (0.4 to 3.3 cm hr1), according to Yitbarek *et al*. (2016).

Sarma *et al*. (1997) examined the physical parameters of two soils (Alfisols and Inceptisols) from different command regions of Assam and found that bulk density was higher in Alfisols and Inceptisols. In comparison to subsurface layers, the surface layer of both soils contains a higher fraction of particles less than 0.25 mm in size. Sand content rose with depth in both soils. Clay was the most dominant factor in determining the physical characteristics of soils.

Sahu and Mishra (1997) assessed the soils of an irrigated river flood plain with in eastern coastal regions, finding that sand and silt content in all pedons reduced as depth increased, demonstrating pedogenic soil formation.

The soils beneath Forest and Pasture in an Agroextractivist Project in eastern Amazonia contained sand and loamy sand in texture mostly in surface strata, with an increase in clay content with depth, according to Zenero *et al.* (2016). Because of the change in structure from granular on the surface to angular and sub angular blocky in the sub-surface horizons, the Bt horizons had the highest bulk density and the lowest macro porosity.

## 2.3 Chemical characteristics

The soils of Vadamalalpeta Mandal in Chittoor district were studied by Kumar and Naidu (2012), who found that they ranged from slightly acidic (pH6.2) to severely alkaline (pH8.8) in reactivity.

Meena *et al*. (2014) analyzed the lowland soils of Karnataka's Chikkarsinkere Hobli, Maddur taluk, Mandya district, and found that the pH of the soils ranged from 7.4 to9.4, the EC ranged from 0.09 to 0.62 dS m-1 with a mean value of 0.27 dS m-1, the OC ranged from 0.7 to 13.7 g kg-1 with a mean value of 5.95 g kg-1, the CEC ranged from 0.57 to 38.7 cmol (p+) kg-1 with a mean value of 15.88 cmol (p+) kg-1.

Goyal and Singh (1998) investigated pedogenic development and soil categorization in basinal areas of various landforms in Southern Haryana, finding that clay and $CaCO_3$ leaching increased with depth, as did the presence of patchy and thin argillan of the argillic horizon and gleization. A general increase in clay/silt fraction with increase in depth revealed moderate to high degree of weathering.

Sahoo*et al.* (2020) investigated Nutrient distribution and relationship with soil properties in different watersheds of Haryana, and found that the available nitrogen (N), phosphorous (P), potassium (K) and sulphur (S) were found to be low (42–189 kg/ha), low to medium (4.2–17.10 kg/ha), low to high (62.2–326.5 kg/ha) and low to high (0.4–19 mg/kg) in the studied pedons, respectively. A positive and significant correlation was observed between N and P (r = 0.71**), N and K (r = 0.70**) and N and S (r = 0.74**) which shows the presence of synergistic effects among these nutrients. Available phosphorous was found to be positively and significantly correlated with OC content (r = 0.89**) showing that higher available P is associated with higher OM (Sharma et al. 2013). Available P was found higher in surface horizon and decrease periodically with depth which could be due to anion replacement of $H_2PO_4$ − ion on adsorption sites on organic matter thereby increasing the quantity of organic P mineralized to inorganic P (Bhat *et al*. 2017).

Swarnam *et al.* (2004) investigated the soils of the Shahibi basin in Delhi and Haryana, finding that the pH was neutral to moderately alkaline (6.5 to 8.04), with low to high organic carbon (0.18 to 0.96 percent) and low to medium CEC (11.5 – 26.5 cmol (p+) $kg^{-1}$) and low to medium CEC (11.5 – 26.5 cmol (p+) $kg^{-1}$. The pH, OC, and CEC of all soils rose increasing depth. Lowland soils had increased organic carbon content and CEC, which could be related to clay translocation and organic carbon content buildup. Throughout the profile, calcium was the most dominant cation, followed by magnesium, sodium, and potassium. Because of excessive runoff from the uplands, upland pedons have lower exchangeable cations than lowland soils. Due to differences in texture and physiography, the base saturation ranged from medium (uplands) to high (lowlands) in the study area.

Devi *et al*. (2015) investigated the sugarcane growing soils of Chittoor District and found that they were non-saline, near neutral (6.90) to strongly alkaline (9.61). (0.01 to 0.41 dS $m^{-1}$). Organic carbon (OC), cation exchange capacity (CEC), and base saturation, ranged from 0.1 to 6.2 g kg-1, 1.05 to 33.34 cmol (p+) $kg^{-1}$, and 54.9 to 93.35 per cent, respectively. Available N was low to medium, available P and K was low to high, and available S was high. In all pedons, save P7, DTPA-extractable Zn was sufficient in surface horizons but deficient in sub-surface horizons, while the soils were poor in DTPA-extractable Fe but sufficient in Cu and Mn.

Mandal (2014) investigated several salt-affected Punjab soils, which revealed a complicated saline and sodic character. Waterlogging and soil salinity developed in coarse texture soils under canal irrigation. Internal drainage was hampered by the presence of concretionary calcium carbonate at subsurface depths, which favoured waterlogging.

When Basavaraju *et al*. (2005) studied soils in the Chandragiri mandal of Chittoor district in Andhra Pradesh, they discovered that the soils were low to medium in organic carbon, slightly acidic to moderately alkaline and cation exchange capacity with wide textural variations, low in available nitrogen, medium in available phosphorus, high in available potassium, but deficient in iron, iron, sulphur and zinc.

Sahoo *et al.* (2010) looked examined the soils on Langol Hill in Imphal, Manipur, and found that the pH ranged from 4.35 to 5.80 at the surface and 4.10 to 5.65 in the subsurface layers. The surface soils have a high organic carbon content ranging from 22.1 to 39.0 g $kg^{-1}$. The CEC was insufficient [10.60 to 19.36 cmol (p+) $kg^{-1}$]. The available nitrogen was high, the available phosphorus was moderate, and the available potassium was medium to high. All of the soils had sufficient DTPA extractable Fe, Mn, Zn, and Cu.

Singh *et al*. (2005) characterised rice-growing soils in Varanasi's eastern region, finding that CEC values ranged from low to medium, indicating clay fractions dominated by illite and kaolinite minerals. Calcium was the most important basic cation in the soil's formation. The primary soil formation processes were illuviation, lessivage, and calcification.

Dinesh *et al*. (2017) investigated the soils of various geomorphic units in north-eastern Haryana, finding that the soils were largely moderate to highly alkaline (7.8-9.4), with the exception of a few pedons in the Shiwalik hills that had a low pH. (6-7.35). Except for superficial strata of forest areas, organic carbon was less than 1%. The river nature of soils caused the uneven distribution of calcium carbonate found in a few pedons. Although all of the soils had low to medium levels of accessible nitrogen, some pedons had higher levels of available phosphorus and potassium.

Pandey and Kumar (2014) found that the highland physiography of old alluvial soils under direct influence of the river Chandan had low organic carbon, reduced CEC, and were neutral to slightly alkaline in reaction while defining the soils of the Chandan river system (pH 6.4 -7.7).

Sekhar et al.(2014) investigated soils in the eastern and central parts of Andhra Pradesh's Prakasam district, which had iso-hyperthermic temperature and ustic soil moisture regimes, and discovered that the soils were slightly acidic to slightly alkaline (pH 6.02 to8.45) in reaction and non-saline. Organic carbon, CEC, and base saturation, respectively, ranged from 0.12 to 0.68 %, 3.48 to 48.74 cmol (p+) $kg^{-1}$, and 73.44 to 91.52 %. Available nitrogen was low, available phosphorus was medium, available potassium was low to high, and available sulphur was high. Except in pedon6, the surface horizon of pedon4, and the sub-surface horizons of pedon2, the soils were insufficient in DTPA-extractable Zn but ample in Cu, Mn, and Fe.

Pulakeshi *et al.* (2014) investigated the soil resources of Mantagani village in Karnataka's northern transitioning agro-climatic zone (zone-8) and found that the soils had an alkaline reaction and that the EC rose with depth (0.10-2.30 dS $m^{-1}$). With increasing depth, the amount of organic carbon decreased and the amount of calcium carbonate rose. The most abundant exchangeable cations were calcium and magnesium, trailed by sodium and potassium.

Yitbarek *et al*. (2016) studied the soils in the Abobo region of western Ethiopia, finding that they were moderately acidic to neutral in pH (5.5 to 7.1) and low to medium in organic carbon (OC) (0.27 to 2.98 percent).

Meena *et al. (*2015) studied upland soils in Chikkarsinkere Hobli and discovered thatpH ranged from 5.6 to8.7, electrical conductivity (EC) varied from 0.02 to 0.37 dS $m^{-1}$with a mean value of 0.12 dS $m^{-1}$, organic carbon (OC) varied from 0.07 to 1.3 g kg-1 with a mean value of 0.70 g $kg^{-1}$, and organic nitrogen (ON) varied from 0.07 The cation exchange capacity (CEC) ranged from 4.4 to 57.7 cmol (p+) $kg^{-1}$, with a mean of 17.02 cmol (p+) $kg^{-1}$, and the CaCO3 concentration ranged from 1 to 2 g $kg^{-1}$, with a mean of 1.6 g kg-1.

Krishna *et al.* (2017) observed at University of Agricultural and Horticultural Sciences, Shivamogga that pH, electrical conductivity, and organic carbon varied from 6.2 to 8.7, 0.11 to 0.84 dS $m^{-1}$ and 3.1 to 5.6 g $kg^{-1}$ respectively. Available N, $P_2O_5$, $K_2O$ varied from 135 to 236 kg $ha^{-1}$, 10 to 34 kg $ha^{-1}$ 130 to 415 kg $ha^{-1}$, respectively. The soils had a low accessible nitrogen content, a low to medium phosphorus content, and a high potassium content. The concentrations of calcium, magnesium, and sulphur were 8.1 to 38.1 cmol (p+) $kg^{-1}$, 6.3 to 26.2 cmol (p+) $kg^{-1}$, and 6.3 to 12.1 mg $kg^{-1}$, respectively. The soils had enough exchangeable calcium and magnesium but were poor in sulphur. Iron, manganese, zinc, and copper were found in concentrations ranging from 0.58 to 5.92 mg $kg^{-1}$, 0.60 to 10.83 mg $kg^{-1}$, 0.01 to 0.41 mg $kg^{-1}$, and 0.06 to 4.81 mg $kg^{-1}$, respectively.

Sahu *et al.* (2001) investigated the morphological characteristics of four Vertisol pedons in Orissa's Western Zone, finding that the soils were unevenly drained, ranging from slightly acid to moderately alkaline, and that alkalinity increased with depth. The soils were rich in base and had a high CEC: clay ratio (0.65 to 0.75).

Electrical conductivity in surface horizons varied from 0.01 to 0.04 $dSm^{-1}$, while electrical conductivity in sub-surface horizons ranged from 0.02 to 0.12 dSm-1, according to Rao *et al.* (2008), and showed fluctuation down the slope gradient.

In the soils of the Sivagiri micro-watershed in the Chittoor district of Andhra Pradesh, Thangasamy *et al*. (2005) found that the pH ranged from mildly acidic (5.83) to strongly alkaline (8.47). The influence of parent material, rainfall, and terrain on soil pH.

According to Meena *et al*. (2006), the pH of soils in Rajasthan's Tonk region ranged from 7.1 to8.6, with an average of7.8, and the relatively highpH of the soils could be attributable to a high degree of base saturation.

Pillai and Natarajan (2004) found that the electrical conductivity of the soils in the Garakahalli watershed ranged from 0.02 to 0.20 dS $m^{-1}$, indicating that the soil is non-saline. These soils, on the other hand, showed no association with depth. This could be owing to the terrain's undulating character, combined with the presence of free drainage, which favoured the evacuation of released bases by percolating and drainage water.

Due to the existing rice-wheat farming pattern and the prevailing semi-arid environment, Singh and Agrawal (2005) found low organic carbon content (1.0 to 5.6 g $kg^{-1}$) in Entisols and Inceptisols of Chandauli district, Uttar Pradesh.

According to Mishra and Ghosh (1995), the CEC values of soils formed from mica-rich parent material ranged from 6.00 to 15.90 cmol (p+) $kg^{-1}$, owing to differences in clay and organic matter content.

Gupta *et al*. (1999) found that the cation exchange capacity in granitic terrain soils in the Jabalpur region of Madhya Pradesh ranged from 14.70 to 55.40 cmol (p+) $kg^{-1}$, with the clay content of the soils being the most important factor.

Gabhane *et al*. (2006) found that the cation exchange capacity of soils varied from 51.16 to 62.98 cmol (p+) $kg^{-1}$in a micro-watershed in the Vidharbha region of Maharashtra, and that soils with lower clay concentration had lower CEC values.

According to Singh and Mishra (1996), the soils in Bihar's Gandak command area were extremely base saturated, with cations on the exchange complex in the following order: Ca2+> Mg2+> K+= Na+.

In the soils of the Sivagiri micro-watershed in Andhra Pradesh's Chittoor district, base saturation ranged from 31 to 92 percent, with exchangeable bases in the order Ca2+> Mg2+> Na+ > K+ (Thangasamy *et al*., 2005).

Misra and Saithantuaanga (2000) investigated the distribution of organic carbon and nitrogen in Teral soils in West Bengal and found that accessible nitrogen in the soil profile declined with depth, following the same trend as organic carbon. High nitrification could explain the comparatively higher amount of $NO^3$—N in the surface horizon.

Gangappa (1989) investigated the soils of the Challakere taluk in the Chitradurga district and found that the accessible phosphorus concentration in red sandy loam and black clay ranged from 2.69 to 80.64 kg $ha^{-1}$. It ranged from 2.72 to 41.20 kg $ha^{-1}$ in profile samples and rose with depth in all of them.

Ashok (2001) looked at 12 soil series representing black, red, and coastal soils from Karnataka's various agro-climatic zones, and 12 surface soil samples from each series were analysed for sulphur status, distribution of different forms of sulphur, and the relationship between sulphur and various soil properties. In black, red, and coastal soils, the $CaCl_2$ recovered sulphur content ranged from 5.08 to59.95, 8.66 to27.15, and 7.26 to 20.32 ppm, respectively.

Bhaskar et al. (2004) studied the distribution of micronutrients in soils on the hill slopes of Meghalaya's Narang-Kongripara watershed. The iron content in the surface horizon varied from 6.1 to 46 mg $kg^{-1}$, while it ranged between 4.22 to 131.8 mg $kg^{-1}$ in the sub-surface.

The soils of the Shikohpur watershed area were characterised by Sitanggang et al. (2006), who found that the soils on the hill top and hill side were somewhat acidic in response, with pH ranging from 6.4 to 6.5. The soils in the ravenous areas, piedmont plain, and alluvial plain were slightly alkaline to alkaline in reaction, whereas the soils in the ravenous areas, piedmont plain, and alluvial plain were slightly alkaline to alkaline (7.55 to 8.57).

**2.4 Soil classification**

Sahoo *et al*. (2019) analysed the soils ofselected watershed area of Haryana, North-west India andclassified the soils as coarse loamy over Typic Torripsamment/ calciorchidsdue to presence of arid/ ustic moisture regime, low organic matter and cation exchange capacity. Chinchmalatpure *et al*. (1998) investigated the soil-site suitability of the Wunna catchment's micro-watershed. The dominating soils on the hilltops and erosion surfaces are entices. These soils are just slightly suited for sorghum production and completely unsuitable for pigeon pea production. On the toe and concave slopes of the basaltic transect, where the finer material from the hill top and foot slope is accumulated, vertisols are the dominant soils. Cotton, sorghum, and pigeon pea grow well on these soils. The ankle slopes of a sandstone transect are where inceptions occur, and these soils are slightly good for sorghum but unsuitable for pigeon pea.

Sindhu *et al*. (2000) investigated the pedological diversity of the Arrival Hills-Yamuna River transect in Haryana's semi-arid region and identified several dominant soils. Piedmont and old flood plain soils were found to be loam to clay loam, moderately to slightly alkaline, and low to medium organic carbon content, and were classed as Inceptisols and Alfisols, respectively, whereas recent flood plain soils were classified as Entisols.

The soils of the Hirna watershed were described and categorised by Gebrekidan and Mishra (2005) as shallow on steep slopes and deep on topographic lows. Because of the basaltic source material, the clay texture was common. When the soil was moistened, the colour often turned to a reddish hue. In reaction, these soils ranged from neutral to alkaline.

The soils of the Kiar-Nagali micro watershed were examined and classed by Tripathi *et al.* (2006), who found that they were neutral to slightly alkaline in response. Nagali-I soils were determined to be unsuitable for cultivation, however Nagali-II and Kundla soils showed high yield potential. The soils of Kundla and Nagali-II were ideal for commercial vegetable crops such as pea and tomato, but only moderately acceptable for wheat and maize. On Nagali-I soils, pastures, forest trees, and medicinal plants will develop more effectively and profitably.

The soils of the Shikohpur watershed basin were described and classified by Sitanggang *et al*. (2006). Entisols and Inceptisols were used to classify the soils of the Shikohpur watershed area in Gurgaon district. Due to a very low degree of soil formation, either due to a lack of available time for growth or an unfavourable pedo-environment, entisols possessed no diagnostic horizons other than ochric epipedon.

Lithic Dystrudepts, Typic Dystrudepts, Typic Kandiudults, Typic Kanhapludalfs, and Typic Hapludalfs were examined by Sahoo *et al*. (2010) and classified as Lithic Dystrudepts, Typic Dystrudepts, Typic Kandiudults, Typic Kanhapludalfs, and Typic Hapludalfs on high.Veeresh *et al.* (2016) investigated soils grown on a toposequence of schist landform in Karnataka's Yadgir district and designated red, brown, and black pedons as Typic Haplustalfs, Vertic Haplustepts, and Leptic Haplusterts, respectively.

Joshi (2014) found that in the dry agro-ecosystem of Jodhpur, marginal and unsuitable regions have been ploughed, resulting in widespread soil degradation. therefore, Two approaches have been proposed to rationalise the extensive and intensive spread of agricultural land use for sustainable crop production: (1) environment-based, taking into account agro-climatic zones, land capability, watershed, and agro-forestry; and (2) soil quality/constraints-based, taking into account sandy, hardpan at shallow depth, and salinity of soil and ground water. Meena *et al*. (2014) investigated the relationship between soil qualities and soybean crop production under rainfed conditions in Bundi district, Rajasthan, and found that 50 percent of the district's total geographical area was appropriate for soybean farming.

Kharlyngdoh *et al*. (2015) identified and characterised the soils of the Micro-watershed of Ri-Bhoi District, Meghalaya in the Eastern Himalayan Agro-climatic Region, including hill tops, hill slopes, and inter hill valleys formed from granite–gneiss occurring under various land uses. Pedon P2 and P3, which are located on the hilltop and hill slopes, respectively, had a cambic (Bw) sub-surface diagnostic horizon and were characterised as

Typic Dystrudepts, whereas pedon P1 on the hilltop and pedon P4 on the hill slope had an argillic (Bt) sub-surface diagnostic horizon and were classified as Typic Paleudalfs. Pedons in the inter-hill valley (P5 and P6), on the other hand, lacked a diagnostic horizon and were thus classed as Oxyaquic Udifluvents and Aeric Endoaquents, respectively.

Gandhi and Savalia (2016) assessed the suitability of soils for wheat in different land slopes of the Girnar toposequence in Gujarat's southern Saurashtra region. Typic soils are those that have a lot of clay in them. Haplustert are good for wheat cultivation, however the soils pertaining to Typic Haplustepts and Typic Ustifluvents are currently not favorable for wheat cultivation. The soils belonging to Lithic Ustorthents and Lithic Haplustepts are not suited for wheat growth.

Dinesh*et al*. (2017) characterised and classified the soils on different Geomorphic Units of North-Eastern Haryana, India and put the Shiwalik hill top, piedmont plain and active and recent flood plains in Entisols order due to lack in pedogenic development and less horizon differentiation and the soils of old alluvial plain in Inceptisol orders due to well developed soil profiles and cambic subsurface horizons.

Sahu *et al*. (2001) identified four Vertisol pedons in the Western Zone of Orissa as Typic/Chromic Haplusterts based on their physical characteristics.

Nagaraju *et al*. (2014) conducted a systematic assessment of Kukadi Command (Minor-25) in Maharashtra's Ahmednagar district and discovered two significant landforms: pediments and piedmont plains. Lithic Ustorthents, Typic Ustorthents, and Typic Haplustepts were soils of pediments and upper piedmonts (erosional surface) that were extremely shallow to shallow in depth, loam to clayey in texture, and also had moderate to severe erosion. Lower piedmont soils (depositional surfaces) were classed as Vertic Haplustepts and Typic Haplusterts and were moderately deep to very deep, fine-textured with shrink-swell potential, and had slight to moderate erosion. The soils were mostly calcareous in character. The soils were divided into land capability sub-classes IIws, IIIes, and IVes, as well as land irrigability sub-classes 2d, 3rd, and 4th. The soil suitability investigation revealed that soils in the pediments and upper piedmont plains were marginally to moderately favourable for cultivating pearl millet, onion, groundnut, wheat, and soybean, while soils in the lower piedmont plains were moderately suitable. Your text will be rewritten by QuillBot. Start by typing or pasting something into this box, then hit the enter key.

Sekhar *et al*. (2014) investigated the soils in the central and eastern regions of Andhra Pradesh's Prakasam district Pedons 2 and 6 were classified as Typic Ustipsamments and Typic Ustorthents, respectively, because there was no sub-surface diagnostic horizon, whereas pedons 1, 4, 5 and 7 were categorised as Typic Haplustepts (pedons 1, 4 and 5) and Lithic Haplustepts (pedons 1, 4 and 5) because there was no sub-surface diagnostic horizon (pedon 7). The pedon 3 was classed under Vertisols and classified as Typic Haplusterts due to presence of vertic features such as slickensides, pressure faces, fissures, and more than 30% clay in all layers. The soils were also tested for the area's most common crops.

Yitbarek *et al*. (2016) found four soil types in the Abobo area in western Ethiopia: Haplic Cambisols (eutric), Vertic Luvisols (hypereutric), Mollic Leptosols (eutric), and Mollic Vertisols (eutric) (hypereutric), were classed as Typic Haplustepts, Vertic Haplustalfs, Lithic Ustorthents, and Typic Haplusterts, respectively, using the World Reference Base and their Soil Taxonomy equivalents.

Devi *et al*. (2015) defined the pedons of the sugarcane producing soils of Chittoor District as Typic Ustorthents (P1, P5, and P6), Ultic Haplustalfs (P2 and P3), Typic Haplustalfs (P4 and P9), Vertic Haplustept (P7 and P11), Typic Ustipsamment (P8), Typic Ustifluvent (P8), and Typic Ustifluvent (P10).

Calcic Ustochrepts, Typic Haplustalfs, Chromic Calciusterts, Typic Rhodustalfs, and Vertic Ustochrepts were named for the red, black, and associated soils of Andhra Pradesh's Giddalur mandal (Gurumurthy *et al*. (1996).

Sharma *et al*. (2004) divided Southern Rajasthan's salt-affected soils into three types: Typic Haplustepts, Typic Calciustepts, and Aridic Ustorthents.

Bandyopadhyay *et al*. (2004) categorised and classified some Jorhat tea-growing soils, reporting that soils on very steep rolling plains (P1 and P2) were classified as Typic Hapludults, while soils on nearly level plains were categorised as Ruptic Ultic Dystrudepts (P3) and Ruptic Alfic Dystrudepts (P4) (P4).

Pedons 1, 3, 4, and 6 are Typic Rhodustalfs, while Pedons 2, 7, and 8 are Rhodic Paleustalfs, and Pedon 5 is Vertic Haplustepts, according to Meena *et al*. (2015) who defined and categorized upland soils of Chikkarsinkere Hobli.

The soils all along toposequence of the Gobeya Sub-Watershed, South Wello Zone, Ethiopia have been classified as Vertic Cambisols (Humic, Hypereutric, Endoskeletic) covering approximately 152.5 ha (30.2 percent), Haplic Regosols (Hypereutric) covering roughly 89.4ha (17.7%), Mollic Leptosols (Humic, Epieutric) covering about 45 ha (8.9%), and Haplic C (Mohammed and colleagues, 2017).

Jena et al. (2016) investigated the soils of the Meghalaya plateau's major landforms, namely denudational hills, plateau, and inter hill valley plain, all of which are formed from granite-gneiss and occur under varying land use, and found that the soils of high denudational hills, highly dissected upper and lower plateau, and low dissected lower plateau are highly weathered (kandic horizons) with base saturation <35%, Ultisols were discovered, and they were classed as such. Alfisols, on the other hand, were categorised as low-denudational hill soils. The moderately fragmented lower plateau and the upper valley region both have alfisols, but the latter has lower base saturation than the former. The soils in the lower valley were classified as Alfisols with an aquic moisture regime.

**CHAPTER-III**

## MATERIALS AND METHODS

To study the characterization and classification of soil properties of Soils of Experimental Area of Department of Soil Science, CCSHAU, Hisar was selected. For this study, nine pedons were selected. This chapter briefly describes the general description of the area, the geographical context of the study area, including relief, drainage, climate, soil sample collection and preparation and the analytical procedures used in the investigation.

**3.1 General description of the area**

- Location of the study area
- Geographical area
- Geology
- Landform, Relief and Drainage
- Climate
- Natural vegetation and Land use

**3.2 Methodology**

- Study of morphological characteristics
- Collection and processing of soil samples

**3.3 Laboratory Analysis**

- Physical characteristics
- Chemical characteristics

**3.4 Soil classification**

**3.5 Land evaluation**

- Land capability
- Land irrigability
- Soil suitability

### 3.1 General description of the study area

The location, physiography, geology, relief, climate, drainage and current land use of the study area are all important factors in any pedogenic investigation, not only for categorization but also for interpretation of the data collected in table 3.1.

**Table 3.1General Characterization of Soils of Experimental Area of Department of Soil Science, Hisar, Haryana**

| Pedon | Profile Site | Physiography | Drainage | Erosion | Land Use | Parent Material | Slope (%) | Slope Direction |
|---|---|---|---|---|---|---|---|---|
| 1 | 60/7 Soil research farm | Alluvial plain | moderately drained | Slight | Cultivated | Alluvium | Nearly flat to very gently sloping (1%) | S-N |
| 2 | 60/14 Soil research farm | Alluvial plain | Well drained | Slight | Cultivated | Alluvium | Nearly flat to very gently sloping (1%) | S-N |
| 3 | 61/5 Soil research farm | Alluvial plain | moderately drained | Slight | Cultivated | Alluvium | Nearly flat to very gently sloping (1%) | S-N |
| 4 | 61/15 Soil research farm | Alluvial plain | moderately drained | Slight | Cultivated | Alluvium | Nearly flat to very gently sloping (1%) | S-N |
| 5 | 62/2 Soil research farm | Alluvial plain | Well drained | Slight | Cultivated | Alluvium | Nearly flat | S-N |
| 6 | 62/6 Soil research farm | Alluvial plain | moderately drained | Slight | Cultivated | Alluvium | Nearly flat | S-N |
| 7 | 62/9 Soil research farm | Alluvial plain | Imperfectly drained | Slight | Cultivated | Alluvium | Nearly levelled | S-N |
| 8 | 63/9 Soil research farm | Alluvial plain | Imperfectly drained | Nil | Cultivated | Alluvium | Nearly levelled | S-N |
|  | 63/14 Soil research farm | Alluvial plain | moderately drained | Nil | Cultivated | Alluvium | Nearly levelled | S-N |

### 3.1.1 Location of the study area

The farm, which is part of the study area, is located to the north-west of the CCS Haryana Agricultural University campus on Hisar-Ludas road which is in the south-western section of the State, 243 kilometres from the state capital Chandigarh and 180 kilometres from the national capital Delhi(Fig. 3.1).

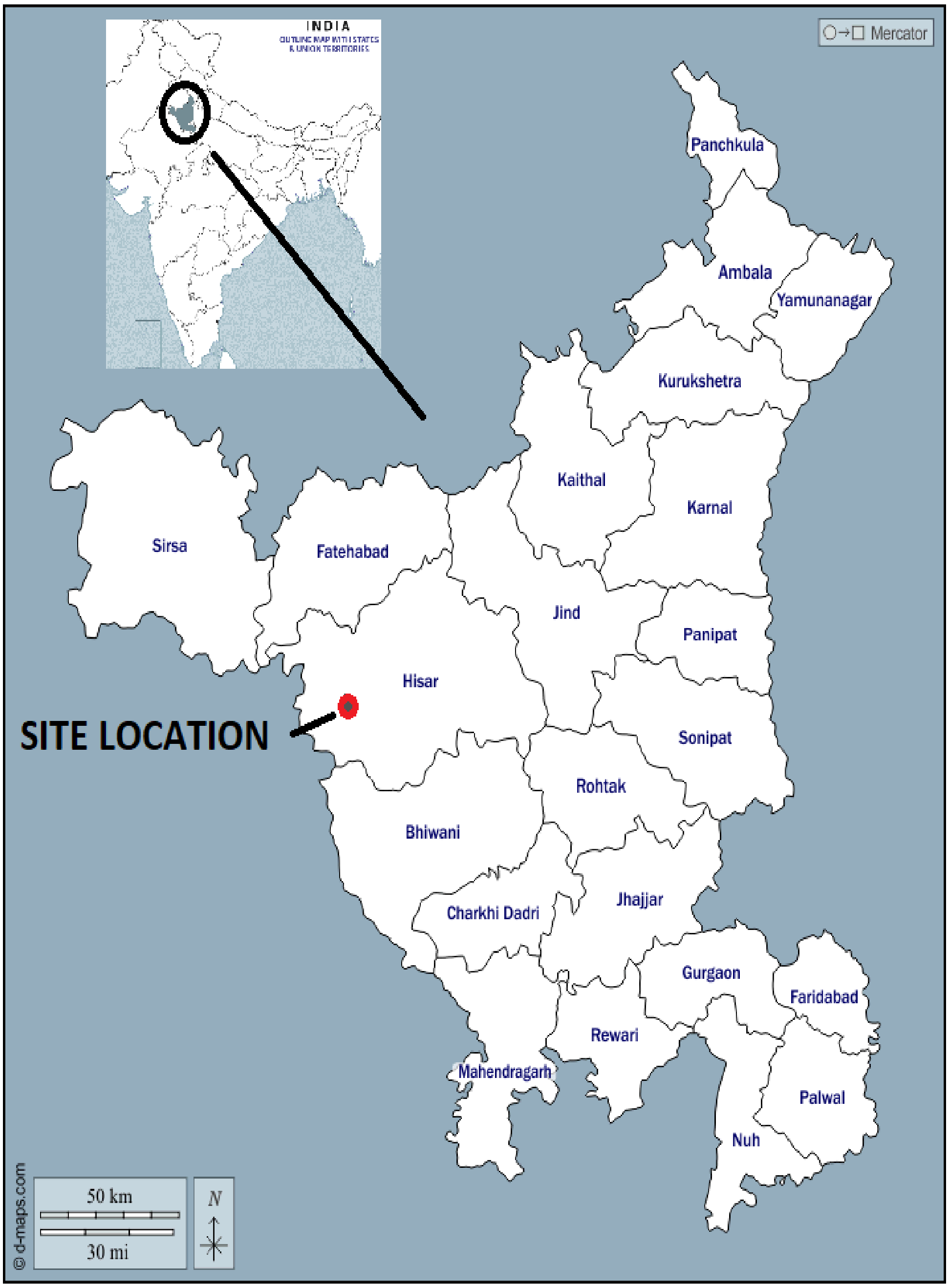



**Figure 3.1 Location map of the study area**

### 3.1.2 Geographical area

The experimental area of department of Soil Science lies between the north latitudes of 29°08'58"N and 29°09'08"N and the longitudes of 75°40'39"E and 75°42'24"E and comprises of 34.1 hactares. The area's typical altitude is 215 metres above sea level.

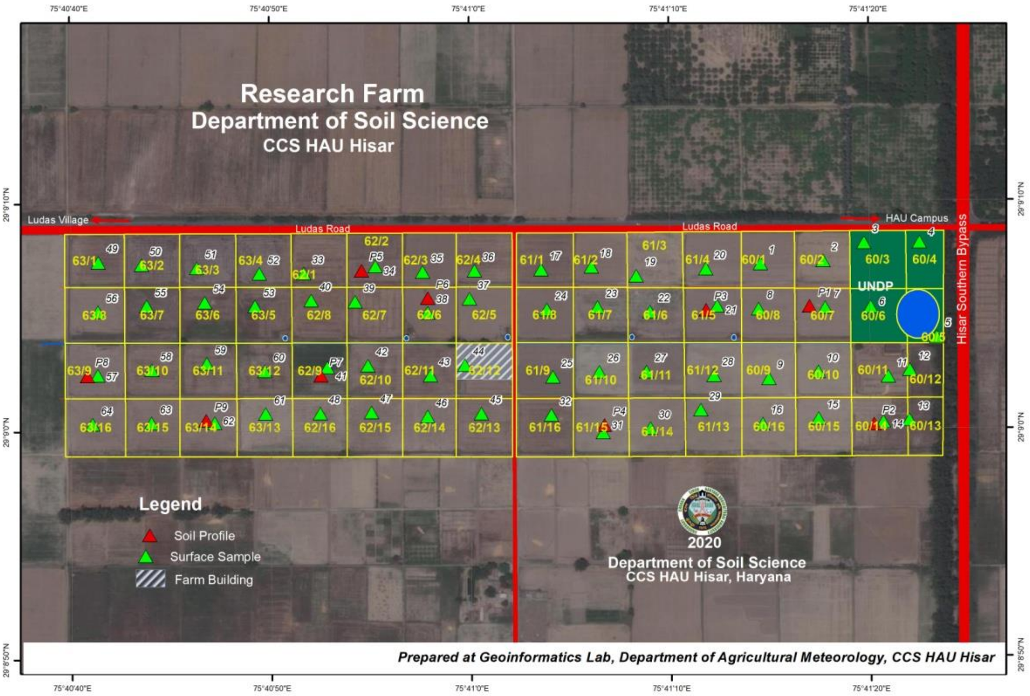



**Fig. 3.2. Soils of Experimental Area of Department of Soil Science**

### 3.1.2 Geology

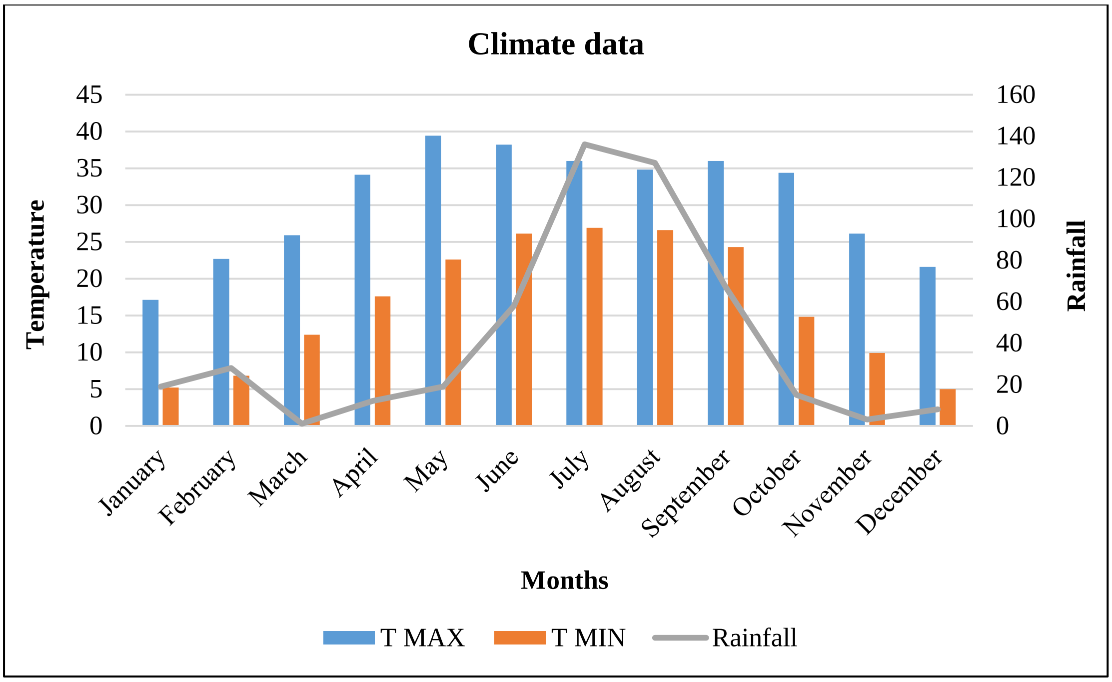
The Indo-Gangetic plain runs through the district. Study area is a mostly alluvial plain with very gentle slope(1% towards north) to flat.The area is part of indo-gangetic alluvial plains with covering of deposits brought down during Pleistocene age. The area has mainly Inseptisols order soils.

### 3.1.3 Landform, Relief and Drainage

Since the area is irrigated with canal and supplemented with tubewell water due to the continous irrigation the water table of the farm appreciably raised upto surface in rainy season and received to 4-5 metres during other period of year. The occurrence of water logging is linked to the problem of salt. Better results are obtained when surface and ground water of mildly saline quality are used together.

### 3.1.4 Climate

Hisar's climate is influenced by its continental location on the outskirts of the SW monsoon area. It has sub-tropical monsoonal type characterized by prolonged hot summer and cool winters and is classified as semi-arid region.




**Source**: Annual report of CCSHAU, Hisar (2020-21)

**Fig. 3.3 Weather data**

The district's average annual rainfall is 133 mm / 5 inch whaereas mean average temperature is 26.27 and hence soil tempertature class is Hyperthermic. The district's climate is characterised by its dryness, temperature fluctuations, and lack of rainfall.

### 3.1.5 Natural vegetation and Land use

The study area is well cultivated however Kikar, Neem, Shisham, Janti, Eucalyptus, and leafless Kair and Jaal are among the principal trees present.The two primary agricultural seasons are kharif and rabi.The kharif season runs from June to September to October, whereas the Rabi season is from October to April.Wheat, gram, and oilseeds are the main rabi crops in the district. Barley, rabi pulses, and vegetables are minor examples.

## 3.2 Methodology

### 3.2.1 Study of morphological characteristics

The morphological properties such as soil colour, texture, structure, consistency, reaction and concretions of different horizons in each pedon were syudied in the field and recorded according to F.A.O Guidelines for soil profile description (1993).

### 3.2.2 Collection and processing of soil samples

For laboratory investigation, representative soil samples from each horizon of the pedons were taken and dried in the shade. The air-dried samples were pulverised with a wooden pestle and mortar, then sieved at 2 mm for coarse fragments (>2 mm) and 0.5 mm for chemical characteristics. Representative Pedons from 1 to 9 are illustrated in plate 1 to 9.

**Plate 1: Representative pedon of 60/7 Soil research farm**

**Plate 2: Representative pedon of 60/14 Soil research farm**

**Plate 3: Representative pedon of 61/5 Soil research farm**

**Plate 4: Representative pedon of 61/15 Soil research farm**

Plate 5: Representative pedon of 62/2 Soil research farm

Plate 6: Representative pedon of 62/6 Soilresearch farm

Plate 7: Representative pedon of 63/9 Soil research farm

Plate 8: Representative pedon of 62/9 Soil research farm

**Plate 9: Representative pedon of 63/14 Soil research farm**

## 3.3 Laboratory Analysis

### 3.3.1 Physical characteristics

#### 3.3.1.1 Mechanical Analysis :

Particle size distribution of the soils was determined by International Pipette method (Piper, 1950) using sodium hydroxide as dispersing agent. From the dispersed suspension an aliquot of clay + silt and clay were pipetted out from specified depth at specific time intervals depending on the suspension temperature.Textural classes were determined using the triangular textural diagram of USDA.

#### 3.3.1.2 Bulk Density:

Bulk density was determined by using Core Method as described in laboratory manual for soil, physical analysis (1999).

#### 3.3.1.3 Particle density:

Particle density was determined by using Pycnometer method as described in laboratory manual for soil physical analysis (1999).

#### 3.3.1.4 Infiltration rate:

Infiltration rate was measured in the field by using double ring close top infiltrometer as described in laboratory manual for soil, physical analysis (1999).

### 3.3.2 Chemical characteristics

All the analytical work carried out as per standard methods/procedures

#### 3.3.2.1 Soil pH:

Soil pH was determined using pH meter consists the glass electrode in 1:2 soil: water suspension at room temperature 25°C. (Jackson, 1973)

#### 3.3.2.2 Electrical conductivity:

Electrical conductivity was determined using a conductivity meter in 1: 2 (soil: water suspension)at room temperature 25°C.(Jackson, 1973)

**3.3.2.3 Organic Carbon:**

Organic carbon content of soil samples was estimated by wet digestion method (Walkley and Black, 1934).

**3.3.2.4 Available Nitrogen:**

Available Nitrogen (N) was determined by alkaline permanganate method (Subbaiah and Asija, 1956).

**3.3.2.5 Available Phosphorus:**

Available P content was determined by extracting the soil samples using 0.5M $NaHCO_3$ and analysed by spectrophotometer (Olsen *et al*., 1954).

**3.3.2.6 Available potassium:**

Available potassium was extracted with neutral normal ammonium acetate (pH 7.0)and the content of potassium in the solution was estimated by Flame Photometer (Jackson,1973).

**3.3.2.7 Calcium carbonate:**

Calcium carbonate was estimated in soil samples by rapid titration method (Puri, 1949).

**3.3.2.8 Cation exchange capacity (CEC):**

Cation Exchange capacity was determined in the extract obtained bv leaching the soil with normal sodium acetate solution (pH 8.2) followed by complete washing with 95 per cent ethanol and final extraction with normal ammonium acetate. Sodium in the resultant extractwas determined with the help of flame photometer. (Hesse, 1971).

**3.3.2.9 Exchangeable cations:**

Exchangeable calcium and magnesium were determined in neutral normal ammonium acetate extract by Versanate Titration method. (Cheng and Bray, 1951).

**3.3.2.10 DTPA extractable Fe, Mn, Cu and Zn:**

The available forms of Fe, Mn, Cu and Zn were extracted by DTPA at pH 7.3 and determined using atomic absorption spectrometer (Lindsay and Norvell, 1978).

**3.4 Soil classification**

Soils were classified according to Soil Taxonomy (Soil Survey Staff, 2006).

**3.5 Land evaluation**

**3.5.1 Land capability**

Land capability class was determined according to Frame work of Land Evaluation (FAO, 1993).

**3.5.2 Land irrigability**

Each pedon site was rated and described for irrigability classes according to Frame work of Land Evaluation (FAO, 1993).

**3.5.3 Soil suitability**

The soil suitability evaluation was carried out according to Frame work of Land Evaluation (FAO, 1993).

## CHAPTER-IV

## RESULTS

### Soil characteristics

Soil characteristics of different pedons excavated in experimental area of Department of Soil Science, CCSHAU Hisar are described as under:

**4.1 Morphological Characteristics**

All the studied pedons were very deep (150+ cm) and exhibited A-B horizonsexcept Pedon 2 which exhibit A-(B)-C1 horizons in profile development.Horizon boundaries of the all the pedons varied from clear to gradual in distinctness and smooth in topography. Roots in all the pedons varied from very few to common in quantity and very fine to medium in size. Coarse fragments were absent in study area except pedons 1, 2 and 3 where it was present in sub-surface horizons varied from >1% ( pedon 1) and <1 in pedon 2 and 3. Calcium carbonate concretions were also present in pedons 1, 2 and 3. Slight to moderate effervescences were observed in pedons 1, 2, 3 and 4 predominantly in sub-surface horizons.

The color of the studied pedons dominant with hue 10YR. The value ranged from 4 to 6, whereas chroma was 3 to 6. The soils of pedon 1 (Table 4.1) showed yellowish brown color throughout the profile (10YR 5/4-10YR 5/6), in color. In pedon 2 the soil color varied from yellowish brown (10YR 5/4) in the horizons Ap, A1, B3 and B4 followed by dark brown (10YR 4/3) whereas in horizons B1 and B2 it was found yellowish brown (10YR 5/4) (Table 4.5). Dark brown color (10YR 4/3) in surface to yellowish brown (10YR 5/4) in sub-surface was observed in pedon 3 (Table 4.9). The soils of pedon 4 were dark yellowish brown (10YR 4/4) in color followed by dark brown (10YR 4/3) in lower-most horizons (Table 4.13).The yellowish brown color (10YR 5/3) were observed in the surface horizon followed by brown (10YR 6/4) in lower horizons in Pedon 5 (Table 4.17). The soils of pedon 6 were dark brown (10YR 4/3) in color followed by yellowish brown (10YR 5/4) in lower horizons (Table 4.17). Dark yellowish brown (10YR 4/4) color was observed in the surface horizon followed by yellowish brown (10YR 5/4) and brown (10YR 6/4) in lower horizons in pedon 7 (Table 4.21). In pedon 8 the soil color was dark brown (10YR 4/3) to yellowish brown (10YR 5/4) in surface and sub-surface, respectively whereas the underlying horizons were observed dark brown (10YR 4/3) (Table 4.33). The soil color of pedon 9 was observed yellowish brown (10YR 5/4) in surface and dark yellowish brown (10YR 4/4) in lower horizons (Table 4.37).

The texture of the studied pedons varied from sandy loam to sandy clay loam.The soils of the study area were derived from alluvium parent material. The texture of pedon 1 and 5 was sandy loam and show inconsequential increase in clay content with depth. The variation in texture within a profile was observed in pedons 2, 4, 8 and 9 with surface horizons dominated by sandy loam to sandy clay loam in lower horizons. The texture of pedons 3, 6 and 7 was found sandy clay loam throughout the profile with slight increase in clay in sub-surface horizons.

The structure of the pedons in experimental area of Department of Soil Science was moderate to strong, medium, sub angular blocky. The structure of pedon 1, 3 and 5 (Table 4.1 4.9 4.17) had moderate, medium-sub angular blocky throughout the profile whereas Pedon 2, 4, 6, 7, 8, 9 exhibited moderate (surface and sub surface) to strong (lower depth), medium (surface and sub surface) to fine (lower depth), sub angular blocky structure (Table 4.5, 4.13, 4.21, 4.25, 4.29, 4.33).

The consistence of all the studied pedons was observed from slightly sticky, non-plastic (surface) to sticky plastic (lower horizons). Pedon 1and 9 were found slightly sticky, non-plastic on surface and slightly sticky, slightly plastic in consistency (Table 4.1, 4.33). The soils of pedon 2, 4 and 5 were found slightly sticky non-slightly plastic on the surface, sticky plastic on subsurface and slightly sticky, slightly plastic in lower horizons in consistency (Table 4.5, 4.13 4.17). The consistency of pedon 3, 6, 7 and 8 was observed slightly sticky slightly plastic (surface and sub-surface) and sticky plastic in lower horizons except pedon 7 which had very sticky very plastic consistency in lowermost (Table 4.9, 4.21, 4.25, 4.29).

**4.2 Physical Characteristics**

The different soil physical properties of different pedons of experimental sites are shown in tables 4.2, 4.6, 4.10, 4.14, 4.18, 4.22, 4.26, 4.30.

**4.2.1 Sand content**

The data revealed that the fraction of soil seperates with the dominancy of sand particles. The amount of sand content in various horizons varied from 68.5 to 71.5 per cent (pedon 1), 61.6 to 71.5 per cent (pedon 2), 62.6 to 65.2 per cent (pedon 3), 61.0 to 71.8 per cent (pedon 4), 68.2 to 70.0 per cent (pedon 5), 60.0 to 64.2 per cent (pedon 6), 59.1 to 61.7 per cent (pedon 7), 64.0 to 69.8 per cent in pedon 8 and 63.8 to 72.2 per cent in pedon 9. The sand content was found maximum in pedon 9 (72.2%) and minimum in pedon 6 (60.0%). The relative proportion of sand among the various horizons of pedons did not exhibit definite trend.

**4.2.2 Silt content**

Content of silt content in soil horizons ranged from 11.4 to 12.5 per cent (pedon 1), 10.1 to 12.5 per cent (pedon 2), 10.1 to 11.5 per cent (pedon 3), 11.0 to 15.9 per cent (pedon 4), 11.9 to 12.8 per cent (pedon 5), 12.5 to 13.4 per cent (pedon 6), 12.8 to 13.2 per cent (pedon 7), 11.4 to 12.9 per cent in (pedon 8) and 12.1 to 15.9 per cent (pedon 9). The silt content was highest B2 horizon in pedon 4 (15.9%) and lowest in surface horizon of pedon 2 (10.1%) and irregular distribution along depth was observed.

#### 4.2.3 Sand content

The fractions of clay in horizons ranged from 17.0 to 19.0 per cent (pedon 1), 17.4 to 28.0 per cent (pedon 2), 23.4 to 27.3 per cent (pedon 3), 17.2 to 26.6 per cent (pedon 4), 18.0 to 19.7 per cent (pedon 5), 22.4 to 27.1 per cent (pedon 6), 25.1 to 27.7 per cent (pedon 7), 18.8 to 23.5 per cent in pedon 8 and 15.7 to 22.8 per cent (pedon 9). In general the clay content increased with depth but did not show regular distribution with depths.

#### 4.2.4 Water retention

The water retention at 0.03 MPa ranged from 16.8 to 20.5 per cent (pedon 1), 17.1 to 19.9 per cent (pedon 2), 16.8 to 20.1 per cent (pedon 3), 16.1 to 19.2 per cent (pedon 4), 18.0 to 19.5 per cent (pedon 5), 18.2 to 20.1 per cent (pedon 6), 18.5 to 21.8 per cent (pedon 7), 17.9 to 20.5 per cent in (pedon 8), 16.8 to 19.6 per cent (pedon 9). Similarly the corresponding values of water retention at 1.5 MPa varied from 6.1 to 7.2per cent (pedon 1), 7.1 to 8.7 per cent (pedon 2), 6.9 to 8.0 per cent (pedon 3), 6.5 to 7.2 per cent (pedon 4), 6.1 to 6.8 per cent (pedon 5), 6.7 to 7.9 per cent (pedon 6), 6.7 to 8.2 per cent (pedon 7), 6.0 to 7.3 per cent in (pedon 8), and 6.2 to 7.2 per cent (pedon 9).

#### 4.2.5 Available water

The available water content showed likely behaviour among different pedons to that of water retention. This varied from 10.7 to 13.8 per cent (pedon 1), 10.3 to 11.3 per cent (pedon 2), 9.9 to 12.1 per cent (pedon 3), 9.6 to 11.4 per cent (pedon 4), 11.9 to 12.5 per cent (pedon 5), 10.9 to 12.8 per cent (pedon 6), 11.8 to 13.6 per cent (pedon 7), 11.9 to 13.2 per cent in pedon 8, 10.6 to 12.8 per cent (pedon 9) and was found highest in pedon 1 (13.8%) and lowest in pedon 4 (9.6%).

#### 4.2.6 Bulk density

The bulk density of soil in different pedons increased with the increase in depth and was found maximum at the lowest horizons. In the different pedons soil bulk density ranged from 1.4 to 1.5 Mg $m^{-3}$ (pedon 1), 1.5 Mg $m^{-3}$ (pedon 2), 1.45 to 1.59 Mg $m^{-3}$ (pedon 3), 1.47 to 1.54 Mg $m^{-3}$ (pedon 4), 1.42 to 1.50 Mg $m^{-3}$ (pedon 5), 1.44 to 1.50 Mg $m^{-3}$ (pedon 6), 1.49 to 1.55 Mg $m^{-3}$ (pedon 7), 1.43 to 1.55 Mg $m^{-3}$ in pedon 8 and 1.48 to 1.59 Mg $m^{-3}$ (pedon 9) respectively. The soil bulk density was maximum in pedon 4 (1.59 Mg $m^{-3}$) and lowest was 1.43 Mg $m^{-3}$ (pedon 7).

#### 4.2.6 Particle density

The particle density followed same trend as that of bulk density. Particle density of different pedons varied from 2.8 to 2.9 Mg $m^{-3}$, 2.9 Mg $m^{-3}$, 2.84 to 2.99Mg $m^{-3}$, 2.97 to 2.99 Mg $m^{-3}$, 2.92 to 2.99 Mg $m^{-3}$, 2.92 to 2.99 Mg $m^{-3}$, 2.94 to 2.99 Mg $m^{-3}$, 2.81to 2.99 Mg $m^{-3}$, and 2.97 to 2.99 Mg $m^{-3}$ of pedon 1, 2, 3, 4, 5, 6, 7, 8 and 9 respectively. The maximum particle density (2.81 Mg $m^{-3}$) was observed in pedon 8 and the lowest value (2.99 Mg $m^{-3}$).

### 4.2.7 Pore space

The pore space of the studied pedons varied from 48.0 to 57.19 and infiltration rate of the soil ranged from 2.1 to 2.4 cm $hr^{-1}$ in the different pedons being highest in pedon 5 and 9 and lowest in pedon 1, 3 and 5.

### 4.3 Chemical Characteristics

The data pertaining to different soil characteristics of pedons 1-9 are presented in Table 4.3, 4.7, 4.11, 4.15, 4.19, 4.23, 4.27, 4.31.

### 4.3.1 pH value

The soils of the study area were slightly alkaline to moderately alkaline (7.5 to 8.5) in reaction whereas the pH value of the soils of the above said pedons varied from 7.7 to 8.4 (pedon 1), 8.0 to 8.4 (pedon 2), 8.1 to 8.3 (pedon 3), 8.0 to 8.3 (pedon 4), 7.4 to 8.1 (pedon 5), 7.8 to 8.1 (pedon 6), 7.6 to 8.3 (pedon 7), 6.4 to 7.8 in (pedon 8), 7.6 to 8.1 per cent in (pedon 9).Amongst different pedons the highest pH of 8.3 was observed in pedon 4 and lowest (6.4) in pedon 8.

### 4.3.2 Electrical conductivity

Soil electrical conductivity of 1:2 soil-water extract varied in range of 0.18 to 0.28 dS $m^{-1}$(pedon 1), 0.16 to 0.34 dS $m^{-1}$ (pedon 2), 0.28 to 0.37 dS $m^{-1}$ (pedon 3), 0.30 to 0.34 dS $m^{-1}$ (pedon 4), 0.24 to 0.32 dS $m^{-1}$ (pedon 5), 0.24 to 032 dS $m^{-1}$ (pedon 6), 0.16 to 0.34 dS $m^{-1}$ (pedon 7), 0.13 to 0.21 dS $m^{-1}$in (pedon 8), 0.26 to 0.36 dS $m^{-1}$ in (pedon 9). The different pedons of the studied area had reduced electrical conductivity at the surface, while deeper horizons had no discernible pattern. In general, the electrical conductivity was non-saline in character, which was attributable to salt accumulation throughout time at varying depths of soil.

### 4.3.3 Calcium carbonate

The soil calcium carbonate in different pedons range from 0.4 to 1.6 per cent (pedon 1 ,2,3,4)and it was totally absent the soils of the pedon 5, 6, 7, 8and 9. Soil organic carbon ranged from 0.15 to 0.64 per cent (pedon 1), 0.17 to 0.64 per cent (pedon 2), 0.15 to 0.60 per cent (pedon 3), 0.20 to 0.55 per cent (pedon 4), 0.27 to 0.58 per cent (pedon 5), 0.28 to 0.62 per cent (pedon 6), 0.27 to 0.40 per cent (pedon 7), 0.24 to 0.39 per cent in (pedon 8), 0.26 to 0.51per cent in (pedon 9).

### 4.3.4 Organic carbon

The organic carbon level of the soil was low to medium in the examined pedons, ranging from 0.15 to 0.64 percent. All of the pedons in the deeper levels showed a declining trend in organic carbon.

### 4.3.5 Cation-exchange capacity

The cation-exchange capacity of the studied pedons varied from 10.5 to 12.9 cmol $(p^{+})$ $kg^{-1}$ (pedon 1), 11.8 to 13.7cmol $(p^{+})$ $kg^{-1}$ (pedon 2), 11.8 to 12.9 cmol $(p^{+})$ $kg^{-1}$ (pedon 3), 11.2 to 12.5 cmol $(p^{+})$ $kg^{-1}$ (pedon 4), 11.8 to 12.8 cmol $(p^{+})$ $kg^{-1}$ (pedon 5), 11.5 to 13.2 cmol $(p^{+})$ $kg^{-}$

$^{1}$(pedon 6), 13.2 to 14.4 cmol ($p^+$) $kg^{-1}$ (pedon 7), 11.3 to 13.1 cmol ($p^+$) $kg^{-1}$ in (pedon 8), 10.2 to 12.1 per cent in (pedon 9). The pedon 7, showed highest CEC (14.4 cmol ($p^+$) $kg^{-1}$) and it was lowest in pedon 6 CEC (10.5 cmol ($p^+$) $kg^{-1}$). A significant correlation coefficient between clay and CEC suggested that clay contributed to the quantity of CEC in these soils.

**4.3.6 Exchangeable Ca**

The analysis of data in different tables (4.3, 4.7, 4.11, 4.15, 4.19, 4.23, 4.27, 4.31) showed that exchangeable Ca in different horizons of the pedons ranged from 4.7 to 8.0 cmol ($p^+$) $kg^{-1}$ (pedon 1), 5.8 to 8.1 cmol ($p^+$) $kg^{-1}$ (pedon 2), 5.6 to 7.5 cmol ($p^+$) $kg^{-1}$ (pedon 3), 5.5 to 7.4 cmol ($p^+$) $kg^{-1}$ (pedon 4), 7.4 to 8.2 cmol ($p^+$) $kg^{-1}$ (pedon 5), 7.1 to 8.6 cmol ($p^+$) $kg^{-1}$ (pedon 6), 1.24 to 2.13 cmol ($p^+$) $kg^{-1}$ (pedon 7), 1.02 to 1.80 cmol ($p^+$) $kg^{-1}$ in (pedon 8), 1.48 to 2.11 cmol ($p^+$) $kg^{-1}$ in (pedon 9). The pedon 6, had highest $Ca^{2+}$ (8.6 cmol ($p^+$) $kg^{-1}$) and it was lowest in pedon 8 (1.02 cmol ($p^+$) $kg^{-1}$).

**4.3.7 Exchangeable Mg**

The exchangeable Mg among different horizons of studied pedons ranged 2.6 to 4.2 cmol ($p^+$) $kg^{-1}$ (pedon 1), 2.7 to 4.2 cmol ($p^+$) $kg^{-1}$ (pedon 2), 2.6 to 4.2 cmol ($p^+$) $kg^{-1}$ (pedon 3), 2.4 to 4.4 cmol ($p^+$) $kg^{-1}$ (pedon 4), 2.6 to 3.7 cmol ($p^+$) $kg^{-1}$ (pedon 5), 2.6 to 4.3 cmol ($p^+$) $kg^{-1}$ (pedon 6), 0.58 to 1.38 cmol ($p^+$) $kg^{-1}$ (pedon 7), 0.68 to 1.40 cmol ($p^+$) $kg^{-1}$ in (pedon 8), 1.36 to 1.51 cmol ($p^+$) $kg^{-1}$ in (pedon 9). The pedon 6 had highest $Mg^{2+}$ (4.3 cmol ($p^+$) $kg^{-1}$). On the other hand, the lowest $Mg^{2+}$ (0.58 cmol ($p^+$) $kg^{-1}$) was observed in pedon 4.

**4.3.8 Exchangeable K**

The exchangeable K among different horizons of studied pedons varied 0.3 to 0.6 cmol ($p^+$) $kg^{-1}$ (pedon 1), 0.4 to 0.6 cmol ($p^+$) $kg^{-1}$ (pedon 2), 0.3 to 0.6 cmol ($p^+$) $kg^{-1}$ (pedon 3), 0.3 to 0.5 cmol ($p^+$) $kg^{-1}$ (pedon 4), 0.4 to 0.6 cmol ($p^+$) $kg^{-1}$ (pedon 5), 0.3 to 0.6 cmol ($p^+$) $kg^{-1}$ (pedon 6), 0.18 to 0.27 cmol ($p^+$) $kg^{-1}$ (pedon 7), 0.18 to 0.33cmol ($p^+$) $kg^{-1}$ in (pedon 8), 0.18 to 0.25 cmol ($p^+$) $kg^{-1}$ in (pedon 9). In the different pedons exchangeable K was found higher in pedons 1, 2, 3, 5, 6 and it showed the highest value to the tune upto 0.6 cmol ($p^+$) $kg^{-1}$. On the other hand, the lowest $K^+$ (0.18 cmol ($p^+$) $kg^{-1}$) was observed among the pedons 7, 8 and 9.

**4.3.9 Exchangeable Na**

The exchangeable Na among different horizons of studied pedons ranged 0.1 to 0.2 cmol ($p^+$) $kg^{-1}$ (pedon 1), 0.1 to 0.4 cmol ($p^+$) $kg^{-1}$ (pedon 2),0.1 to 0.3 cmol ($p^+$) $kg^{-1}$ (pedon 3), 0.1 to 0.5cmol ($p^+$) $kg^{-1}$ (pedon 4), 0.2 to 0.5 cmol ($p^+$) $kg^{-1}$ (pedon 5), 0.2 to 0.5 cmol ($p^+$) $kg^{-1}$ (pedon 6), 0.17 to 0.66 cmol ($p^+$) $kg^{-1}$ (pedon 7), 0.31 to 0.62 cmol ($p^+$) $kg^{-1}$ in (pedon 8), 0.23 to 0.47 cmol ($p^+$) $kg^{-1}$ in (pedon 9). This shows that the pedon 7, had highest $Na^+$ complex (0.66 cmol ($p^+$) $kg^{-1}$). On the other hand, the lowest $Na^+$ (0.1 cmol ($p^+$) $kg^{-1}$) was observed in pedon 1,2,3 and 4.

Magnesium was dominant cation among the exchange complex and it ranged 0.5 to 4.3 cmol ($p^+$) $kg^{-1}$ followed by calcium and varied from 1.02 to 8.6 cmol ($p^+$) $kg^{-1}$. Exchangeable sodium was placed next in the order and varied from 0.1 to 0.6 cmol ($p^+$) $kg^{-1}$ in all the pedons whereas exchangeable K was found more or less constant ranging from 0.1 to 0.6 cmol ($p^+$) $kg^{-1}$. In all the pedons, cations followed the order $Mg^{2+}$ > $Ca^{2+}$> $Na^+$> $K^+$.

**4.3.10 Exchangeable Sodium percentage and Base Saturation Percentage**

Exchangeable Sodium percentage (ESP) and Base Saturation Percentage (BSP) availed between 0.95 to 4.2 % and 84.3 to 114.7 %, respectively. The pedon 8, A1 horizon had highest ESP (4.2 %) and the lowest (0.95 %) was observed in B1 horizon of pedon 3. The pedon 6, Ap horizon had highest BSP (114.78 %). On the other hand, the lowest BSP (84.36 %) was observed in A1 horizon of pedon 6.

**4.4 Nutrient status**

The data regarding nutrient status of soil of pedons 1-9 are present in tables 4.4, 4.8, 4.12, 4.16, 4.20, 4.24, 4.28, 4.32.

**4.4.1 Available Nitrogen**

This showed that availability of nitrogen in studied soil was low and it ranged from 56 to 144 kg $ha^{-1}$(pedon 1), 84 to 8 kg $ha^{-1}$ (pedon 2), 70 to 126 kg $ha^{-1}$ (pedon 3), 84 to 142 kg $ha^{-1}$ (pedon 4), 84 to 140 kg $ha^{-1}$ (pedon 5), 89 to 126 kg $ha^{-1}$ (pedon 6), 98 to 128 kg $ha^{-1}$ (pedon 7), 112 to 134 kg $ha^{-1}$ in (pedon 8), 84 to 132 kg $ha^{-1}$ in (pedon 9). In different pedons the available N in soil was more at shallow depth and it decreased in the deeper layer of soil depth. The highest value (134 kg $ha^{-1}$) available N content in soil was found on Ap horizon of pedon 8 whereas, lowest value (56 kg $ha^{-1}$) in B2 horizon of pedon 1.

**4.4.2 Available Phosphorus**

The experimental soil was low to medium in available P ranging from 4 to 10 kg $ha^{-1}$ (pedon 1), 4 to 8 kg $ha^{-1}$ (pedon 2), 4 to 8 kg $ha^{-1}$ (pedon 3), 4 to 10 kg $ha^{-1}$ (pedon 4), 4 to 8 kg $ha^{-1}$ (pedon 5), 4 to 10 kg $ha^{-1}$ (pedon 6), 4 to 8 kg $ha^{-1}$ (pedon 7), 4 to 12 kg $ha^{-1}$ in (pedon 8), 6 to 8 kg $ha^{-1}$ in (pedon 9). The availability of phosphorus was highest (10 kg $ha^{-1}$) of available P content was found in pedons 1, 4 and 6 whereas, lowest Olsen P reached (4 kg $ha^{-1}$) in all pedons except pedon 9.

**4.4.3 Available Potassium**

The data indicated that these soils were medium to high in available K ranging from 240 to 340 (pedon 1), 240 to 420 kg $ha^{-1}$ (pedon 2), 260 to 380 kg $ha^{-1}$ (pedon 3), 240 to 340 kg $ha^{-1}$ (pedon 4), 340 to 384 kg $ha^{-1}$ (pedon 5), 340 to 412 kg $ha^{-1}$ (pedon 6), 420 to 480 kg $ha^{-1}$ (pedon 7), 290 to 400 kg $ha^{-1}$ in (pedon 8), 284 to 380 kg $ha^{-1}$ in (pedon 9). The highest value (480 kg $ha^{-1}$) of available K content was found in Ap horizon of pedon 7 whereas, minimum value (240 kg $ha^{-1}$) in pedon 1, 2 and 4. By examining the above results it was found that availability of macronutrients was highest at surface soil and this decreased with increase in depth. The trend was similar in all of the pedons.

**4.4.4 DTPA-extractable Fe**

The data presented in tables (table 4.4, 4.8, 4.12, 4.16, 4.20, 4.24, 4.28, 4.32, 4.36) revealed that the DTPA-extractable Fe ranged from 1.04 to 2.49 mg $kg^{-1}$ (pedon 1), 0.36 to 1.50 mg $kg^{-1}$ (pedon 2), 1.31 to 2.44 mg $kg^{-1}$ (pedon 3), 1.49 to 2.20 mg $kg^{-1}$ (pedon 4), 1.96 to 2.09 mg $kg^{-1}$ (pedon 5), 1.19 to 1.94 mg $kg^{-1}$ (pedon 6), 1.26 to 3.87 mg $kg^{-1}$ (pedon 7), 3.58 to 1.47 mg $kg^{-1}$ in (pedon 8), 1.33 to 3.04 mg $kg^{-1}$ in (pedon 9). The highest value DTPA-extractable Fe content (2.49 mg $kg^{-1}$) was found at Ap horizon whereas, lowest value (1.04 mg $kg^{-1}$) was found in C horizon of pedon 1.

**4.4.5 DTPA-extractable Zn**

The DTPA-extractable Zn ranged from 0.54 to 1.60 mg $kg^{-1}$ (pedon 1), 0.56 to 1.72 mg $kg^{-1}$ (pedon 2), 0.33 to 1.33 mg $kg^{-1}$ (pedon 3), 0.22 to 1.22 mg $kg^{-1}$ (pedon 4), 0.35 to 1.50 mg $kg^{-1}$ (pedon 5), 0.29 to 1.26 mg $kg^{-1}$ (pedon 6), 0.27 to 1.26 mg $kg^{-1}$ (pedon 7), 0.25 to 1.24 mg $kg^{-1}$ in (pedon 8), 0.26 to 1.24 mg $kg^{-1}$ in (pedon 9). The maximum value (1.80 mg $kg^{-1}$) of DTPA-extractable Zn content was found in Ap horizon of pedon 8 whereas, lowest value (0.22 mg $kg^{-1}$) at C1 horizon of pedon 4.

**4.4.6 DTPA-extractable Mn**

The DTPA-extractable Mn ranged from 1.03 to 1.13 mg $kg^{-1}$ (pedon 1), 1.05 to 1.60 mg $kg^{-1}$ (pedon 2), 1.40 to 1.55 mg $kg^{-1}$ (pedon 3), 1.43 to 2.73 mg $kg^{-1}$ (pedon 4), 0.94 to 2.69 mg $kg^{-1}$ (pedon 5), 0.94 to 1.23 mg $kg^{-1}$ (pedon 6), 0.94 to 1.23 mg $kg^{-1}$ (pedon 7), 1.14 to 3.27 mg $kg^{-1}$ in (pedon 8), 1.59 to 2.98 mg $kg^{-1}$ in (pedon 9). The maximum value (3.27 mg $kg^{-1}$) of DTPA-extractable Mn content was found in B3 horizon of pedon 8 whereas, lowest value (0.94 mg $kg^{-1}$) in Ap horizon of pedon 5 and 6.

**4.4.7 DTPA-extractable Cu**

The DTPA-extractable Cu ranged from 0.48 to 0.75 mg $kg^{-1}$ (pedon 1), 0.28 to 0.48 mg $kg^{-1}$ (pedon 2), 0.42 to 0.64 mg $kg^{-1}$ (pedon 3), 0.49 to 0.60 mg $kg^{-1}$ (pedon 4), 0.23 to 0.46 mg $kg^{-1}$ (pedon 5), 0.64 to 3.21 mg $kg^{-1}$ (pedon 6), 0.37 to 0.79 mg $kg^{-1}$ (pedon 7), 0.51 to 0.76 mg $kg^{-1}$ in ((pedon 8), 0.39 to 0.54 mg $kg^{-1}$ in (pedon 9). The maximum value (3.21 mg $kg^{-1}$) of DTPA-extractable Cu content was found in B1 horizon of pedon 6 whereas, lowest value (0.23 mg $kg^{-1}$) of Cu was recorded in B2 and Ap horizon of pedon 5.

The abundance of DTPA-extractable micronutrients in different pedons showed no discernible trend with depth.

**Pedon No.** : **1**
**Classification** : Coarse loamy Calcareous, Mixed, Hyperthermic, Typic Haplustepts
**Location** : 60/7 Soil research farm, CCS HAU Hisar (29° 15149’ N latitude, 75° 68804’ E longitude)
**Physiography** : Alluvial plain
**Erosion** : Slight
**Drainage** : moderately drained
**Slope** : Nearly flat to very gently sloping (1%)
**Slope Direction** : S-N
**Parent Material** : Alluvium
**Present land use** : Cultivated

**Table 4.1 Morphological characteristics**

| Horizon | Depth (cm) | Horizon boundary | Color (moist) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction |
|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-19 | c-s | 10YR 5/4 | sl | 2 m sbk | SSNP | - | f m | **-** | **-** |
| A1 | 19-50 | c-s | 10YR 5/5 | sl | 2 m sbk | SSSP | - | vffn | **>1.0** | **1** |
| B1 | 50-85 | c-s | 10YR 5/5 | sl | 2 m sbk | SSSP | - | vffn | **>1.0** | **2** |
| B2 | 85-135 | c-s | 10YR 5/6 | sl | 2 m sbk | SSSP | - | - | **>1.0** | **1** |
| B3 | 135-180+ | - | 10YR 5/6 | sl | 2 m sbk | SSSP | - | - | **-** | **-** |

**Table 4.2 Physical properties of pedon 1**

| Horizon | Depth (cm) | Sand (%) (2.0-0.05mm) | Silt (%) (0.05-0.002mm) | Clay (%) (<0.002mm) | Texture | Bulk Density | Particle density | Percent Moisture retention (MPa) | | Pore space (%) | Available water (%) | Infiltration Rate (cm $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Mg $m^{-3}$) | | 0.03 | 1.5 | | | |
| Ap | 0-19 | 69.2 | 12.1 | 17.7 | sl | 1.4 | 2.8 | 20.5 | 6.7 | 48.0 | 13.8 | 2.1 |
| A1 | 19-50 | 68.5 | 12.5 | 19.0 | sl | 1.5 | 2.9 | 19.8 | 7.2 | 49.1 | 12.6 | |
| B1 | 50-85 | 71.2 | 11.8 | 17.0 | sl | 1.5 | 2.9 | 19.7 | 6.8 | 48.9 | 12.9 | |
| B2 | 85-135 | 71.4 | 11.6 | 17.0 | sl | 1.5 | 2.9 | 18.5 | 6.4 | 48.8 | 12.1 | |
| B3 | 135-180+ | 71.5 | 11.4 | 17.1 | sl | 1.5 | 2.9 | 16.8 | 6.1 | 48.9 | 10.7 | |

**Table 4.3 Chemical properties of pedon 1**

| Horizon | Depth (cm) | pH (1:2) | EC | OC | $CaCO_3$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | CEC | ESP | BSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ($dS\ m^{-1}$) | (%) | (%) | $cmol(p^+)\ kg^{-1}$ | | | | | | |
| Ap | 0-19 | 7.7 | 0.24 | 0.64 | - | 7.7 | 2.6 | 0.2 | 0.6 | 12.2 | 1.80 | 90.98 |
| A1 | 19-50 | 7.9 | 0.18 | 0.30 | 1.2 | 8.0 | 2.8 | 0.3 | 0.6 | 12.9 | 2.56 | 90.69 |
| B1 | 50-85 | 8.1 | 0.19 | 0.33 | 1.8 | 5.7 | 4.2 | 0.1 | 0.3 | 11.7 | .97 | 88.03 |
| B2 | 85-135 | 8.4 | 0.21 | 0.33 | 1.5 | 5.6 | 4.0 | 0.1 | 0.4 | 10.7 | 0.99 | 94.39 |
| B3 | 135-180+ | 8.3 | 0.28 | 0.15 | 0.5 | 4.7 | 4.1 | 0.1 | 0.3 | 10.5 | 1.08 | 87.61 |

**Table 4.4 Available Nutrient status of pedon 1**

| Horizon | Depth (cm) | Available macronutrients ($kg\ ha^{-1}$) | | | Available micronutrients ($mg\ kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Zn | Fe | Cu | Mn |
| Ap | 0-19 | 144 | 10 | 340 | 1.60 | 2.49 | 0.75 | 1.13 |
| A1 | 19-50 | 126 | 6 | 240 | 0.54 | 1.31 | 0.70 | 1.12 |
| B1 | 50-85 | 70 | 4 | 240 | 1.26 | 0.81 | 0.60 | 1.03 |
| B2 | 85-135 | 84 | 4 | 260 | 0.26 | 1.04 | 0.56 | 1.04 |
| B3 | 135-180+ | 56 | 4 | 300 | 0.54 | 2.28 | 0.48 | 1.07 |

**Pedon No.** : **2**
**Classification** : Fine loamy, Mixed, Hyperthermic,CalcareousTypicHaplustepts
**Location** : 60/14 Soil researchfarm , CCS HAU Hisar (29° 15005' N latitude, 75° 68893' E longitude)
**Physiography** : Alluvial plain
**Erosion** : Slight
**Drainage** : Well drained
**Slope** : Nearly flat to very gently sloping (1%)
**Slope Direction** : S-N
**Parent Material** : Alluvium
**Present land use** : Cultivated

**Table 4.5 Morphological characteristics**

| Horizon | Depth (cm) | Horizon boundary | Color (moist) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction |
|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-20 | c-s | 10YR 5/4 | sl | 2 m sbk | SSNP | - | f m | - | - |
| A1 | 20-40 | a-s | 10YR 5/4 | scl | 2 m sbk | SSSP | - | vffn | - | - |
| B1 | 40-90 | c-s | 10YR 4/3 | scl | 3 f sbk | SP | - | vffn | >1 | 2 |
| B2 | 58-90 | c-s | 10YR 4/3 | scl | 3 f sbk | SP | - | - | <1 | 2 |
| B3 | 90-128 | c-s | 10YR 5/4 | scl | 3 f sbk | SP | - | - | - | 1 |
| B4 | 128-160 | c-s | 10YR 5/4 | sl | 3 f sbk | SSSP | - | - | - | - |
| C1 | 160-210 | - | 10YR 5/3 | sl | 3 f sbk | SSSP | - | - | - | - |

**Table 4.6 Physical properties of pedon 2**

| Horizon | Depth (cm) | Sand (%) (2.0-0.05mm) | Silt (%) (0.05-0.002mm) | Clay (%) (<0.002mm) | Texture | Bulk density | Particle density | Percent moisture retention (Mpa) | | Pore space (%) | Available water (%) | Infiltration Rate (cm $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Mg $m^{-3}$) | | 0.03 | 1.5 | | | |
| Ap | 0-20 | 71.5 | 11.8 | 17.7 | sl | 1.5 | 2.9 | 18.5 | 8.2 | 49.32 | 10.3 | |
| A1 | 20-40 | 61.6 | 10.4 | 28.0 | scl | 1.5 | 2.9 | 19.9 | 8.7 | 48.99 | 11.2 | |
| B1 | 40-90 | 64.7 | 11.0 | 24.3 | scl | 1.5 | 2.9 | 19.8 | 8.5 | 48.98 | 11.3 | |
| B2 | 58-90 | 65.6 | 11.2 | 18.9 | scl | 1.5 | 2.9 | 17.7 | 7.2 | 48.16 | 10.5 | 2.2 |
| B3 | 90-128 | 69.2 | 10.1 | 20.7 | scl | 1.5 | 2.9 | 18.2 | 7.1 | 48.14 | 11.1 | |
| B4 | 128-160 | 70.1 | 12.5 | 17.4 | sl | 1.5 | 2.9 | 17.1 | 6.4 | 48.16 | 10.7 | |
| C1 | 160-210 | 69.5 | 12.4 | 18.1 | sl | 1.5 | 2.9 | 17.2 | 6.5 | 48.32 | 10.7 | |

**Table 4.7 Chemical properties of pedon 2**

| Horizon | Depth (cm) | pH (1:2) | EC | OC | $CaCO_3$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | CEC | ESP | BSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (dS $m^{-1}$) | (%) | (%) | cmol($p^+$) $kg^{-1}$ | | | | | | |
| Ap | 0-20 | 8.0 | 0.26 | 0.64 | 0.90 | 8.0 | 2.9 | 0.2 | 0.4 | 12.2 | 1.73 | 94.26 |
| A1 | 20-40 | 8.3 | 0.16 | 0.42 | 0.45 | 7.9 | 3.1 | 0.3 | 0.6 | 13.7 | 2.52 | 86.86 |
| B1 | 40-90 | 8.4 | 0.33 | 0.27 | 0.55 | 8.1 | 4.2 | 0.3 | 0.4 | 13.2 | 2.30 | 98.48 |
| B2 | 58-90 | 8.1 | 0.34 | 0.26 | 0.75 | 7.9 | 3.1 | 0.2 | 0.5 | 12.3 | 1.70 | 95.1 |
| B3 | 90-128 | 8.1 | 0.24 | 0.29 | 0.70 | 7.5 | 3.6 | 0.5 | 0.5 | 12.6 | 4.13 | 96.03 |
| B4 | 128-160 | 8.2 | 0.25 | 0.17 | 0.72 | 8.1 | 2.7 | 0.4 | 0.6 | 11.8 | 3.38 | 99.99 |
| C1 | 160-210 | 8.1 | 0.23 | 0.32 | 0.80 | 5.8 | 4.2 | 0.1 | 0.4 | 11.9 | 0.95 | 88.23 |

**Table 4.8 Available Nutrient status of pedon 2**

| Horizon | Depth (cm) | Available macronutrients (kg $ha^{-1}$) | | | Available micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Zn | Fe | Cu | Mn |
| Ap | 0-20 | 142 | 8 | 420 | 1.50 | 1.72 | 0.42 | 1.12 |
| A1 | 20-40 | 124 | 4 | 260 | 1.40 | 1.03 | 0.46 | 1.09 |
| B1 | 40-90 | 98 | 6 | 240 | 0.64 | 0.83 | 0.48 | 1.05 |
| B2 | 58-90 | 70 | 4 | 240 | 1.16 | 0.70 | 0.36 | 1.07 |
| B3 | 90-128 | 112 | 4 | 280 | 0.34 | 0.56 | 0.28 | 1.12 |
| B4 | 128-160 | 84 | 4 | 280 | 0.36 | 1.01 | 0.30 | 1.50 |
| C1 | 160-210 | 84 | 4 | 300 | 0.59 | 1.26 | 0.40 | 1.60 |

**Pedon No.** : **3**
**Classification** : Fine loamy, Mixed, Hyperthermic,Calcareous, Typic Ustochrepts
**Location** : 61/5 Soil research farm, CCS HAU Hisar (29$^{o}$ 15145'N latitude, 75$^{o}$ 68660' E longitude)
**Physiography** : Alluvial plain
**Erosion** : Slight
**Drainage** : Moderately drained
**Slope** : Nearly flat to very gently sloping (1%)
**Slope Direction** : S-N
**Parent Material** : Alluvium
**Present land use** : Cultivated

**Table 4.9 Morphological characteristics**

| Horizon | Depth (cm) | Horizon boundary | Color (moist) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction |
|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-23 | c-s | 10YR 4/3 | Scl | 2 m sbk | SSSP | - | f m | - | - |
| A1 | 23-55 | c-s | 10YR 5/4 | Scl | 2 m sbk | SSSP | - | vffn | >1 | 2 |
| B1 | 55-125 | c-s | 10YR 5/4 | Scl | 2 f sbk | SP | - | vffn | <1 | 1 |
| B2 | 125-149 | c-s | 10YR 4/3 | Scl | 3 f sbk | SP | - | - | - | 1 |
| B3 | 149-180+ | - | 10YR 4/3 | Scl | 3 f sbk | SSSP | - | - | - | - |

**Table 4.10 Physical properties of pedon 3**

| Horizon | Depth (cm) | Sand (%) (2.0-0.05mm) | Silt (%) (0.05-0.002mm) | Clay (%) (<0.002mm) | Texture | Bulk density | Particle density | Percent moisture retention (Mpa) | | Pore space (%) | Available water (%) | Infiltration Rate (cm hr$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Mg m$^{-3}$) | | 0.03 | 1.5 | | | |
| Ap | 0-23 | 62.6 | 10.1 | 27.3 | Scl | 1.45 | 2.84 | 20.1 | 8.0 | 51.05 | 12.1 | 2.1 |
| A1 | 23-55 | 63.7 | 11.2 | 26.1 | Scl | 1.49 | 2.88 | 18.8 | 7.9 | 51.73 | 10.9 | |
| B1 | 55-125 | 64.6 | 11.5 | 24.9 | Scl | 1.54 | 2.96 | 17.8 | 7.4 | 52.02 | 10.4 | |
| B2 | 125-149 | 65.2 | 10.5 | 24.3 | Scl | 1.57 | 2.98 | 17.2 | 7.1 | 52.68 | 10.1 | |
| B3 | 149-180+ | 65.1 | 10.8 | 23.4 | Scl | 1.59 | 2.99 | 16.8 | 6.9 | 44.04 | 9.9 | |

**Table 4.11 Chemical properties of pedon 3**

| Horizon | Depth (cm) | pH (1:2) | EC | OC | $CaCO_3$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | CEC | ESP | BSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (dS $m^{-1}$) | (%) | (%) | cmol($p^+$) $kg^{-1}$ | | | | | | |
| Ap | 0-23 | 8.2 | 0.37 | 0.60 | - | 7.5 | 2.7 | 0.2 | 0.6 | 12.9 | 1.81 | 82.94 |
| A1 | 23-55 | 8.3 | 0.30 | 0.33 | 2.30 | 7.4 | 2.6 | 0.3 | 0.6 | 12.7 | 2.75 | 85.82 |
| B1 | 55-125 | 8.1 | 0.28 | 0.15 | 0.50 | 5.8 | 4.2 | 0.1 | 0.4 | 11.9 | 0.95 | 88.23 |
| B2 | 125-149 | 8.1 | 0.36 | 0.22 | - | 5.6 | 4.0 | 0.2 | 0.5 | 11.8 | 1.94 | 87.28 |
| B3 | 149-180+ | 8.2 | 0.32 | 0.18 | - | 5.9 | 4.1 | 0.2 | 0.3 | 11.8 | 1.90 | 88.98 |

**Table 4.12 Available Nutrient status of pedon 3**

| Horizon | Depth (cm) | Available macronutrients (kg $ha^{-1}$) | | | Available micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Zn | Fe | Cu | Mn |
| Ap | 0-23 | 126 | 8 | 360 | 1.20 | 1.68 | 0.42 | 1.40 |
| A1 | 23-55 | 121 | 6 | 345 | 1.33 | 2.44 | 0.48 | 1.40 |
| B1 | 55-125 | 108 | 8 | 380 | 0.41 | 2.00 | 0.52 | 1.55 |
| B2 | 125-149 | 77 | 4 | 360 | 0.36 | 1.96 | 0.57 | 1.34 |
| B3 | 149-180+ | 70 | 6 | 260 | 0.33 | 1.31 | 0.64 | 1.42 |

**Pedon No.** : **4**
**Classification** : Fine loamy, Mixed, Hyperthermic, Calcareous Typic Haplustepts
**Location** : 61/15 Soil research farm, CCS HAU Hisar (29$^o$ 15005'N latitude, 75$^o$ 68518' E longitude)
**Physiography** : Alluvial plain
**Erosion** : Slight
**Drainage** : Well drained
**Slope** : Nearly flat to very gently sloping (1%)
**Slope Direction** : S-N
**Parent Material** : Alluvium
**Present land use** : Cultivated

**Table 4.13 Morphological characteristics**

| Horizon | Depth (cm) | Horizon boundary | Color (moist) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction |
|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-22 | c-s | 10YR 4/4 | sl | 2 m sbk | SSNP | - | f m | - | - |
| A1 | 22-50 | c-s | 10YR 4/4 | scl | 2 m sbk | SSSP | - | vffn | >1 | 2 |
| B1 | 50-90 | c-s | 10YR 4/3 | scl | 2 m sbk | SP | - | vffn | <1 | 1 |
| B2 | 90-125 | c-s | 10YR 4/3 | scl | 3 f sbk | SP | - | - | - | 1 |
| B3 | 125-160+ | - | 10YR 4/3 | scl | 3 f sbk | SP | - | - | - | - |

**Table 4.14 Physical properties of pedon 4**

| Horizon | Depth (cm) | Sand (%) (2.0-0.05mm) | Silt (%) (0.05-0.002mm) | Clay (%) (<0.002mm) | Texture | Bulk density | Particle density | Percent moisture retention (Mpa) | | Pore space (%) | Available water (%) | Infiltration Rate (cm hr$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Mg m$^{-3}$) | | 0.03 | 1.5 | | | |
| Ap | 0-22 | 71.8 | 11.0 | 17.2 | Sl | 1.47 | 2.94 | 16.8 | 6.9 | 50.58 | 9.9 | 2.2 |
| A1 | 22-50 | 61.0 | 12.4 | 26.6 | Scl | 1.49 | 2.95 | 19.2 | 7.2 | 49.49 | 12 | |
| B1 | 50-90 | 63.5 | 13.2 | 23.3 | Scl | 1.52 | 2.97 | 18.5 | 7.1 | 48.82 | 11.4 | |
| B2 | 90-125 | 64.6 | 15.9 | 19.5 | Scl | 1.54 | 2.99 | 16.8 | 6.8 | 48.49 | 10 | |
| B3 | 125-160+ | 68.3 | 12.6 | 19.1 | Scl | 1.54 | 2.99 | 16.1 | 6.5 | 48.49 | 9.6 | |

**Table 4.15 Chemical properties of pedon 4**

| Horizon | Depth (cm) | pH (1:2) | EC | OC | $CaCO_3$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | CEC | ESP | BSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (dS $m^{-1}$) | (%) | (%) | cmol($p^+$) $kg^{-1}$ | | | | | | |
| Ap | 0-22 | 8.0 | 0.31 | 0.55 | - | 5.5 | 4.4 | 0.1 | 0.5 | 11.8 | 0.95 | 88.98 |
| A1 | 22-50 | 8.3 | 0.32 | 0.33 | 1.6 | 7.4 | 3.6 | 0.5 | 0.5 | 12.5 | 4.16 | 96.00 |
| B1 | 50-90 | 8.2 | 0.30 | 0.20 | 0.80 | 7.0 | 2.4 | 0.4 | 0.5 | 12.0 | 3.88 | 85.83 |
| B2 | 90-125 | 8.1 | 0.34 | 0.26 | - | 7.2 | 3.7 | 0.2 | 0.3 | 11.8 | 1.75 | 96.61 |
| B3 | 125-160+ | 8.1 | 0.30 | 0.26 | - | 7.1 | 3.6 | 0.5 | 0.5 | 11.2 | 4.31 | 103.57 |

**Table 4.16 Available Nutrient status of pedon 4**

| Horizon | Depth (cm) | Available macronutrients (kg $ha^{-1}$) | | | Available micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Zn | Fe | Cu | Mn |
| Ap | 0-22 | 142 | 10 | 260 | 1.22 | 2.20 | 0.60 | 1.52 |
| A1 | 22-50 | 98 | 6 | 300 | 0.39 | 1.49 | 0.55 | 1.58 |
| B1 | 50-90 | 84 | 4 | 240 | 0.22 | 1.66 | 0.50 | 1.56 |
| B2 | 90-125 | 112 | 6 | 280 | 0.30 | 1.70 | 0.53 | 2.73 |
| B3 | 125-160+ | 112 | 8 | 340 | 0.26 | 1.56 | 0.49 | 1.43 |

| | | |
|---|---|---|
| **Pedon No.** | : | **5** |
| **Classification** | : | Fine loamy, Mixed, Hyperthermic, Typic Haplustepts |
| **Location** | : | 62/2 Soil research farm, CCS HAU Hisar (29$^o$ 15195'N latitude,75$^o$ 68181' E longitude) |
| **Physiography** | : | Alluvial plain |
| **Erosion** | : | Slight |
| **Drainage** | : | Well drained |
| **Slope** | : | Nearly flat |
| **Slope Direction** | : | S-N |
| **Parent Material** | : | Alluvium |
| **Present land use** | : | Cultivated |

**Table 4.19 Morphological characteristics**

| Horizon | Depth (cm) | Horizon boundary | Color (moist) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction |
|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-15 | c-s | 10YR 5/3 | sl | 2 m sbk | SSNP | - | f m | - | - |
| A1 | 15-59 | a-s | 10YR 5/4 | sl | 2 m sbk | SP | - | vffn | - | - |
| B1 | 59-115 | c-s | 10YR 5/4 | sl | 2m sbk | SP | - | vffn | - | - |
| B2 | 115-145 | g-s | 10YR 6/4 | sl | 2 m sbk | SSSP | - | - | - | - |
| Water Table Reached | | | | | | | | | | |

**Table 4.18 Physical properties of pedon 5**

| Horizon | Depth (cm) | Sand (%) (2.0-0.05mm) | Silt (%) (0.05-0.002mm) | Clay (%) (<0.002mm) | Texture | Bulk density | Particle density | Percent moisture retention (Mpa) | | Pore space (%) | Available water (%) | Infiltration Rate (cm hr$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Mg m$^{-3}$) | | 0.03 | 1.5 | | | |
| Ap | 0-15 | 69.8 | 12.2 | 18.0 | Sl | 1.42 | 2.92 | 18.7 | 6.2 | 51.36 | 12.5 | 2.4 |
| A1 | 15-59 | 68.2 | 12.1 | 19.7 | Sl | 1.49 | 2.95 | 19.5 | 6.8 | 49.49 | 12.7 | |
| B1 | 59-115 | 70.0 | 12.8 | 19.2 | Sl | 1.49 | 2.95 | 18.5 | 6.5 | 50.50 | 12.0 | |
| B2 | 115-145 | 69.2 | 11.9 | 18.9 | Sl | 1.50 | 2.99 | 18.0 | 6.1 | 50.16 | 11.9 | |
| Water Table Reached | | | | | | | | | | | | |

**Table 4.19 Chemical properties of pedon 5**

| Horizon | Depth (cm) | pH (1:2) | EC | OC | $CaCO_3$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | CEC | ESP | BSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (dS $m^{-1}$) | (%) | (%) | cmol($p^{+}$) $kg^{-1}$ | | | | | | |
| Ap | 0-15 | 7.4 | 0.26 | 0.58 | - | 8.1 | 2.8 | 0.2 | 0.4 | 12.2 | 1.78 | 91.80 |
| A1 | 15-59 | 8.0 | 0.32 | 0.30 | - | 8.1 | 3.7 | 0.4 | 0.6 | 12.8 | 3.12 | 99.99 |
| B1 | 59-115 | 8.1 | 0.24 | 0.27 | - | 7.4 | 3.5 | 0.5 | 0.5 | 12.4 | 4.31 | 93.54 |
| B2 | 115-145 | 7.9 | 0.24 | 0.41 | - | 8.2 | 2.6 | 0.4 | 0.6 | 11.8 | 3.38 | 100 |
| Water Table Reached | | | | | | | | | | | | |

**Table 4.20 Available Nutrient status of pedon 5**

| Horizon | Depth (cm) | Available macronutrients (kg $ha^{-1}$) | | | Available micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Zn | Fe | Cu | Mn |
| Ap | 0-15 | 140 | 8 | 384 | 1.50 | 2.09 | 0.46 | 2.69 |
| A1 | 15-59 | 124 | 6 | 340 | 0.38 | 2.00 | 0.36 | 0.94 |
| B1 | 59-115 | 84 | 4 | 380 | 0.35 | 1.96 | 0.30 | 1.44 |
| B2 | 115-145 | 98 | 4 | 340 | 0.39 | 2.05 | 0.23 | 2.68 |
| Water Table Reached | | | | | | | | |

**Pedon No.** : **6**
**Classification** : Coarse loamy, Mixed, Hyperthermic, Typic Haplustepts
**Location** : 62/6 Soil research farm, CCS HAU Hisar (29$^{o}$ 15161'N latitude, 75$^{o}$ 68273' E longitude)
**Physiography** : Alluvial plain
**Erosion** : Slight
**Drainage** : moderately drained
**Slope** : Nearly flat to very gently sloping (1%)
**Slope Direction** : S-N
**Parent Material** : Alluvium
**Present land use** : Cultivated

**Table 4.21 Morphological characteristics**

| Horizon | Depth (cm) | Horizon boundary | Color (moist) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction |
|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-16 | c-s | 10YR 4/3 | scl | 2 m sbk | SSSP | - | f m | - | - |
| A1 | 16-46 | c-s | 10YR 5/4 | scl | 2 m sbk | SSSP | - | vffn | - | - |
| B1 | 46-77 | c-s | 10YR 5/4 | scl | 3 f sbk | SP | - | vffn | - | - |
| B2 | 77-130 | c-s | 10YR 4/3 | scl | 3 f sbk | SP | - | - | - | - |
| B3 | 130-160+ | - | 10YR 4/3 | scl | 3 f sbk | SP | - | - | - | - |

**Table 4.22 Physical properties of pedon 6**

| Horizon | Depth (cm) | Sand (%) (2.0-0.05mm) | Silt (%) (0.05-0.002mm) | Clay (%) (<0.002mm) | Texture | Bulk density | Particle Density | Percent moisture retention (Mpa) | | Pore space (%) | Available water (%) | Infiltration Rate (cm hr$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Mg m$^{-3}$) | | 0.03 | 1.5 | | | |
| Ap | 0-16 | 64.2 | 13.4 | 22.4 | Scl | 1.44 | 2.95 | 18.2 | 7.3 | 57.19 | 10.9 | |
| A1 | 16-46 | 61.2 | 12.5 | 26.3 | Scl | 1.44 | 2.92 | 19.8 | 7.9 | 50.68 | 11.9 | |
| B1 | 46-77 | 60.0 | 12.9 | 27.1 | Scl | 1.47 | 2.97 | 20.1 | 7.8 | 50.50 | 12.3 | 2.3 |
| B2 | 77-130 | 61.4 | 13.1 | 25.5 | Scl | 1.50 | 2.99 | 19.1 | 6.9 | 49.83 | 12.2 | |
| B3 | 130-160+ | 60.2 | 13.2 | 26.6 | Scl | 1.49 | 2.95 | 19.5 | 6.7 | 49.49 | 12.8 | |

**Table 4.23 Chemical properties of pedon 6**

| Horizon | Depth (cm) | pH (1:2) | EC | OC | $CaCO_3$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | CEC | ESP | BSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (dS $m^{-1}$) | (%) | (%) | cmol($p^+$) $kg^{-1}$ | | | | | | |
| Ap | 0-16 | 7.8 | 0.32 | 0.62 | - | 8.6 | 3.9 | 0.4 | 0.3 | 11.5 | 3.02 | 114.78 |
| A1 | 16-46 | 8.0 | 0.30 | 0.45 | | 7.2 | 2.6 | 0.4 | 0.6 | 12.8 | 3.70 | 84.37 |
| B1 | 46-77 | 8.1 | 0.28 | 0.38 | - | 8.1 | 4.2 | 0.5 | 0.4 | 13.2 | 3.70 | 100 |
| B2 | 77-130 | 8.0 | 0.28 | 0.28 | - | 7.1 | 4.3 | 0.4 | 0.5 | 12.4 | 3.25 | 99.11 |
| B3 | 130-160+ | 8.0 | 0.24 | 0.26 | - | 8.2 | 3.7 | 0.2 | 0.3 | 12.8 | 1.69 | 96.87 |

**Table 4.24 Available Nutrient status of pedon 6**

| Horizon | Depth (cm) | Available macronutrients (kg $ha^{-1}$) | | | Available micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Zn | Fe | Cu | Mn |
| Ap | 0-16 | 126 | 10 | 412 | 0.84 | 1.94 | 0.25 | 3.21 |
| A1 | 16-46 | 102 | 6 | 400 | 0.30 | 1.88 | 0.26 | 0.64 |
| B1 | 46-77 | 98 | 8 | 340 | 0.21 | 1.80 | 0.28 | 0.90 |
| B2 | 77-130 | 89 | 4 | 340 | 0.26 | 1.33 | 0.36 | 0.89 |
| B3 | 130-160+ | 94 | 6 | 340 | 0.20 | 1.19 | 0.42 | 0.86 |

| | | |
|---|---|---|
| **Pedon No.** | : | **7** |
| **Classification** | : | Fine loamy, Mixed, Hyperthermic, Typic Haplustepts |
| **Location** | : | 62/9 Soil research farm, CCS HAU Hisar (29$^{o}$ 15067'N latitude, 75$^{o}$ 68124' E longitude) |
| **Physiography** | : | Low lying alluvial plain |
| **Erosion** | : | Slight |
| **Drainage** | : | Imperfectly drained |
| **Slope** | : | Nearly levelled |
| **Slope Direction** | : | S-N |
| **Parent Material** | : | Alluvium |
| **Present land use** | : | Cultivated |

**Table 4.25 Morphological characteristics**

| Horizon | Depth (cm) | Horizon boundary | Color (moist) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction |
|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-20 | c-s | 10YR 4/4 | Scl | 2 m sbk | SSSP | - | f m | - | - |
| A1 | 20-41 | c-s | 10YR 5/4 | Scl | 2 f sbk | SSSP | - | vffn | - | - |
| B1 | 41-80 | c-s | 10YR 5/4 | Scl | 2 m sbk | SSSP | - | vffn | - | - |
| B2 | 80-125 | c-s | 10YR 6/4 | Scl | 3 f sbk | SP | - | - | - | - |
| B3 | 125-155+ | - | 10YR 6/4 | Scl | 3 f sbk | VSVP | - | - | - | - |

**Table 4.26 Physical properties of pedon 7**

| Horizon | Depth (cm) | Sand (%) (2.0-0.05mm) | Silt (%) (0.05-0.002mm) | Clay (%) (<0.002mm) | Texture | Bulk density | Particle density | Percent moisture retention (Mpa) | | Pore space (%) | Available water (%) | Infiltration Rate (cm hr$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Mg m$^{-3}$) | | 0.03 | 1.5 | | | |
| Ap | 0-20 | 60.6 | 12.8 | 26.6 | Scl | 1.51 | 2.97 | 20.3 | 7.9 | 49.15 | 12.4 | 2.4 |
| A1 | 20-41 | 59.1 | 13.2 | 27.7 | Scl | 1.49 | 2.94 | 21.8 | 8.2 | 49.31 | 13.6 | |
| B1 | 41-80 | 60.1 | 12.9 | 27.0 | Scl | 1.51 | 2.97 | 21.1 | 7.8 | 49.15 | 13.3 | |
| B2 | 80-125 | 61.0 | 13.0 | 26.0 | Scl | 1.52 | 2.98 | 19.1 | 6.9 | 48.99 | 12.2 | |

**Table 4.27 Chemical properties of pedon 7**

| Horizon | Depth (cm) | pH (1:2) | EC | OC | $CaCO_3$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | CEC | ESP | BSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (dS $m^{-1}$) | (%) | (%) | cmol($p^+$) $kg^{-1}$ | | | | | | |
| Ap | 0-20 | 7.6 | 0.20 | 0.40 | - | 10.1 | 3.2 | 0.4 | 0.3 | 14.2 | 1.51 | 97.88 |
| A1 | 20-41 | 8.2 | 0.16 | 0.34 | - | 8.7 | 4.7 | 0.4 | 0.5 | 14.4 | 2.85 | 97.22 |
| B1 | 41-80 | 8.3 | 0.29 | 0.36 | - | 8.4 | 2.6 | 0.3 | 0.6 | 13.8 | 2.23 | 97.10 |
| B2 | 80-125 | 8.2 | 0.39 | 0.27 | - | 8.3 | 4.3 | 0.5 | 0.5 | 13.5 | 2.94 | 100.74 |
| B3 | 125-155+ | 8.1 | 0.39 | 0.29 | - | 8.5 | 3.4 | 0.3 | 0.4 | 13.2 | 2.25 | 100.75 |

**Table 4.28 Available Nutrient status of pedon 7**

| Horizon | Depth (cm) | Available macronutrients (kg $ha^{-1}$) | | | Available micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Zn | Fe | Cu | Mn |
| Ap | 0-20 | 128 | 8 | 480 | 1.26 | 1.26 | 0.40 | 0.94 |
| A1 | 20-41 | 114 | 6 | 420 | 0.27 | 1.77 | 0.37 | 1.12 |
| B1 | 41-80 | 108 | 4 | 440 | 0.29 | 1.54 | 0.79 | 1.16 |
| B2 | 80-125 | 98 | 6 | 440 | 0.27 | 1.60 | 0.70 | 1.23 |
| B3 | 125-155+ | 98 | 7 | 420 | 0.28 | 3.87 | 0.61 | 1.16 |

| | | |
|---|---|---|
| **Pedon No.** | : | **8** |
| **Classification** | : | Fine loamy, Mixed, Hyperthermic, Typic Haplustepts |
| **Location** | : | 63/9 Soil research farm, CCS HAU Hisar ($29^o$ 15068'N latitude, $75^o$ 67799' E longitude) |
| **Physiography** | : | Alluvial plain |
| **Erosion** | : | Nil |
| **Drainage** | : | Imperfectly drained |
| **Slope** | : | Nearly levelled |
| **Slope Direction** | : | S-N |
| **Parent Material** | : | Alluvium |
| **Present land use** | : | Cultivated |

**Table 4.29 Morphological characteristics**

| Horizon | Depth (cm) | Horizon boundary | Color (moist) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction |
|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-17 | c-s | 10YR 4/3 | sl | 2 m sbk | SSSP | - | f m | - | - |
| A1 | 17-52 | g-s | 10YR 5/4 | scl | 2 m sbk | SSSP | - | Vffn | - | - |
| B1 | 52-100 | c-s | 10YR 4/4 | scl | 3 m sbk | SP | - | Vffn | - | - |
| B2 | 100-142 | c-s | 10YR 4/3 | scl | 3 f sbk | SP | - | - | - | - |
| B3 | 142-170+ | c-s | 10YR 4/3 | scl | 3 f sbk | SP | - | - | - | - |
| Water Table | | | | | | | | | | |

**Table 4.30 Physical properties of pedon 8**

| Horizon | Depth (cm) | Sand (%) (2.0-0.05mm) | Silt (%) (0.05-0.002mm) | Clay (%) (<0.002mm) | Texture | Bulk density | Particle density | Percent moisture retention (Mpa) | | Pore space (%) | Available water (%) | Infiltration Rate (cm $hr^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Mg $m^{-3}$) | | 0.03 | 1.5 | | | |
| Ap | 0-17 | 69.8 | 11.4 | 18.8 | Sl | 1.46 | 2.87 | 17.9 | 6.0 | 49.12 | 11.9 | 2.21 |
| A1 | 17-52 | 64.2 | 12.7 | 21.3 | Scl | 1.43 | 2.81 | 19.3 | 6.4 | 49.11 | 12.9 | |
| B1 | 52-100 | 64.0 | 12.5 | 23.5 | Scl | 1.52 | 2.97 | 20.5 | 7.3 | 48.82 | 13.2 | |
| B2 | 100-142 | 65.2 | 12.9 | 21.9 | Scl | 1.55 | 2.99 | 19.8 | 6.7 | 48.16 | 13.1 | |
| B3 | 142-170+ | 65.9 | 11.8 | 22.3 | Scl | 1.55 | 2.99 | 20.1 | 6.9 | 48.16 | 13.2 | |
| Water Table | | | | | | | | | | | | |

**Table 4.31 Chemical properties of pedon 8**

| Horizon | Depth (cm) | pH (1:2) | EC | OC | $CaCO_3$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | CEC | ESP | BSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (dS $m^{-1}$) | (%) | (%) | cmol($p^+$) $kg^{-1}$ | | | | | | |
| Ap | 0-17 | 6.4 | 0.13 | 0.39 | - | 6.3 | 4.5 | 0.1 | 0.3 | 11.3 | 0.89 | 99.11 |
| A1 | 17-52 | 6.8 | 0.21 | 0.28 | - | 7.6 | 3.2 | 0.5 | 0.5 | 12.4 | 4.2 | 95.16 |
| B1 | 52-100 | 7.8 | 0.14 | 0.27 | - | 7.7 | 2.5 | 0.3 | 0.6 | 13.1 | 2.70 | 84.73 |
| B2 | 100-142 | 7.6 | 0.17 | 0.24 | - | 7.0 | 2.4 | 0.4 | 0.5 | 12.0 | 3.88 | 86.08 |
| B3 | 142-170+ | 7.5 | 0.09 | 0.24 | -- | 7.8 | 3.9 | 0.4 | 0.5 | 12.5 | 3.17 | 100.8 |
| Water Table | | | | | | | | | | | | |

**Table 4.32 Available Nutrient status of pedon 8**

| Horizon | Depth (cm) | Available macronutrients (kg $ha^{-1}$) | | | Available micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Zn | Fe | Cu | Mn |
| Ap | 0-17 | 130 | 12 | 400 | 1.80 | 1.47 | 0.51 | 1.14 |
| A1 | 17-52 | 124 | 8 | 380 | 0.25 | 4.21 | 0.53 | 2.04 |
| B1 | 52-100 | 112 | 4 | 322 | 0.36 | 3.83 | 0.57 | 2.34 |
| B2 | 100-142 | 120 | 4 | 312 | 0.46 | 3.58 | 0.97 | 2.57 |
| B3 | 142-170+ | 134 | 4 | 290 | 0.69 | 3.58 | 0.76 | 2.98 |
| Water Table | | | | | | | | |

**Pedon No.** : **9**
**Classification** : Fine loamy, Mixed, Hyperthermic, Typic Ustochrepts
**Location** : 63/14 Soil research farm, CCS HAU Hisar (29$^o$ 15013'N latitude, 75$^o$ 67964' E longitude)
**Physiography** : Alluvial plain
**Erosion** : Nil
**Drainage** : moderately drained
**Slope** : Nearly levelled
**Slope Direction** : S-N
**Parent Material** : Alluvium
**Present land use** : Cultivated

**Table 4.33 Morphological characteristics**

| Horizon | Depth (cm) | Horizon boundary | Color (moist) | Texture | Structure | Consistence | Cutans | Roots | Coarse fragment | Reaction |
|---|---|---|---|---|---|---|---|---|---|---|
| Ap | 0-18 | c-s | 10YR 5/4 | sl | 2 m sbk | SSNP | - | f m | - | - |
| A1 | 18-90 | c-s | 10YR 5/4 | scl | 2 m sbk | SSSP | - | vffn | - | - |
| B1 | 90-135 | c-s | 10YR 4/4 | scl | 3 m sbk | SSSP | - | vffn | - | - |
| B2 | 135-172 | c-s | 10YR 4/4 | scl | 3 m sbk | SSSP | - | - | - | - |
| Water Table | | | | | | | | | | |

**Table 4.34 Physical properties of pedon 9**

| Horizon | Depth (cm) | Sand (%) (2.0-0.05mm) | Silt (%) (0.05-0.002mm) | Clay (%) (<0.002mm) | Texture | Bulk density | Particle Density | Percent moisture retention (Mpa) | | Pore space (%) | Available water (%) | Infiltration Rate (cm hr$^{-1}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (Mg m$^{-3}$) | | 0.03 | 1.5 | | | |
| Ap | 0-18 | 72.2 | 12.1 | 15.7 | Sl | 1.48 | 2.97 | 16.8 | 6.2 | 50.16 | 10.6 | 2.1 |
| A1 | 18-90 | 64.1 | 13.2 | 22.7 | Scl | 1.51 | 2.97 | 19.6 | 6.8 | 49.15 | 12.8 | |
| B1 | 90-135 | 63.8 | 13.4 | 22.8 | Scl | 1.59 | 2.98 | 19.2 | 7.2 | 46.64 | 12.2 | |
| B2 | 135-172 | 64.6 | 15.9 | 19.5 | Scl | 1.55 | 2.99 | 18.9 | 7.1 | 48.16 | 11.8 | |
| Water Table | | | | | | | | | | | | |

**Table 4.35 Chemical properties of pedon 9**

| Horizon | Depth (cm) | pH (1:2) | EC | OC | $CaCO_3$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^{+}$ | $K^{+}$ | CEC | ESP | BSP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (dS $m^{-1}$) | (%) | (%) | cmol($p^{+}$) $kg^{-1}$ | | | | | | |
| Ap | 0-18 | 7.6 | 0.36 | 0.51 | - | 7.1 | 2.8 | 0.2 | 0.4 | 10.2 | 1.9 | 102.9 |
| A1 | 18-90 | 8.1 | 0.31 | 0.32 | - | 7.2 | 3.7 | 0.2 | 0.3 | 11.5 | 1.75 | 99.13 |
| B1 | 90-135 | 8.1 | 0.28 | 0.32 | - | 7.9 | 3.0 | 0.3 | 0.4 | 12.1 | 2.58 | 95.86 |
| B2 | 135-172 | 8.0 | 0.26 | 0.26 | - | 5.6 | 4.3 | 0.1 | 0.5 | 10.9 | 0.95 | 96.33 |
| Water Table | | | | | | | | | | | | |

**Table 4.36 Available Nutrient status of pedon 9**

| Horizon | Depth (cm) | Available macronutrients (kg $ha^{-1}$) | | | Available micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | | N | P | K | Zn | Fe | Cu | Mn |
| Ap | 0-18 | 132 | 8 | 300 | 1.24 | 3.04 | 0.54 | 2.98 |
| A1 | 18-90 | 126 | 6 | 284 | 0.29 | 1.65 | 0.52 | 3.27 |
| B1 | 90-135 | 98 | 6 | 380 | 0.26 | 1.59 | 0.48 | 1.65 |
| B2 | 135-172 | 84 | 8 | 340 | 0.34 | 1.33 | 0.39 | 1.59 |
| Water Table | | | | | | | | |

## 4.5 LAND EVALUATION

### (a) Land Capability Classification

The land capability classification is an interpretation grouping of various soil units that helps with land use planning, reclamation of problematic soils, and soil suitability for crop cultivation and irrigation management.The soils of all the nine pedons under investigation were examined for land capability classification using the Frame work of Land Evaluation (FAO, 1993, 2014).The sub-class criteria were based on terrain limitations such as the risk of erosion and runoff (e), sub-surface coarse fragments, texture, shallow depth, low water holding capacity, salinity, alkalinity (s) and cation exchange capacity (f), base saturation percent (f), organic carbon (f).The results revealed (Table 4.37) that due to the limitations of texture, cation exchange capacity and organic carbon, the soils were classed as Ids and Is according to Land Capability Classification. The soils of pedon 1 and 3 were put under LCC class Ids due to low fertility status, drainage and less cation exchange capacity. Rest of the soils were placed in LCC class Is due to low fertility and less cation exchange capacity problems.

### (b) LandIrrigability

The soils experimental area was evaluated for irrigability classification based on the land qualities given by Frame work of Land Evaluation (FAO, 1993). The criteria for subclass were used as soil drainage (d), topography (t) and soil limitations (s). The results presented in Table 4.38 inferred that all the pedons are put under S1s.

### (c) Soil Suitability Classification

Soil suitability classification was evaluated using Frame work of Land Evaluation (FAO, 1993). The soils were examined for different agricultural crops, vegetable crops, forest and horticultural plantation. The compatibility of categories created are as follows:

| **Order** | **Class** |
|---|---|
| S | Suitable |
| S1 | Highly suitable = Land having no significant limitation or Slight limitation. |
| S2 | Moderately suitable = Land having moderate limitation. |
| S3 | Marginally suitable=Land having severe limitation |
| N | Not suitable=Land which cannot be corrected by acceptable methodand cost. |

The soil suitability rating for different crops were evaluated and presented in Table 4.39. The soils of pedon 1 and 2 were suitable for wheat, barley, cotton, pearl millet, forestry, oilseed (Raya) and moderately to marginally suitable for Pulses, Pulses, horticulture and Vegetable. The soils pedon 3 were placed in suitable class for wheat, barley, Oilseeds, pearl millet and moderately to marginally suitable for forestry, Pulses, Pulses, horticulture and Vegetable. The soils pedon 4 were placed in suitable class for barley, pearl millet, forestry, horticulture, oilseed (Raya) and moderately to marginally suitable for Pulses, and cotton.

**Table 4.37: Land capability classification**

| Sl. No. | Soil unit | Land form characteristics | | | | | Physical characteristics | Chemical characteristics | | | | LCC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Slope (%) | Erosion | Drainage | Depth (cm) | Profile development | Texture | EC ($dSm^{-1}$) | OC (%) | CEC (cmol (p+) $kg^{-1}$) | Base saturation | |
| 1. | Pedon 1 | I | II | II | I | I | I | I | III | III | I | Ids |
| 2. | Pedon 2 | I | II | I | I | I | III | I | III | III | I | Is |
| 3. | Pedon 3 | I | I | II | I | I | III | I | III | III | I | Ids |
| 4. | Pedon 4 | I | I | II | II | I | III | I | III | III | I | Is |
| 5. | Pedon 5 | I | I | I | II | I | II | I | III | III | I | Is |
| 6. | Pedon 6 | II | I | I | I | I | III | I | III | III | I | Is |
| 7. | Pedon 7 | I | I | I | I | I | III | I | III | III | IV | Is |
| 8. | Pedon 8 | II | I | I | I | I | III | I | III | III | I | Is |
| | Pedon 9 | I | I | I | I | I | III | I | III | III | I | Is |

**Table 4.38 : Soil suitability classification for irrigation**

| Sl. No. | Soil unit | Land form characteristics | | | Physical characteristic | Chemical characteristics | | | Suitability sub-class |
|---|---|---|---|---|---|---|---|---|---|
| | | Slope (%) | Drainage | Depth (cm) | Texture | EC (dS $m^{-1}$) | ESP (%) | Free $CaCO_3$ | |
| 1. | Pedon 1 | **S1** | **S1** | **S1** | **S2** | **S1** | **S1** | **S2** | **S1s** |
| 2. | Pedon 2 | **S1** | **S1** | **S1** | **S2** | **S1** | **S1** | **S2** | **S1s** |
| 3. | Pedon 3 | **S1** | **S1** | **S1** | **S2** | **S2** | **S1** | **S2** | **S1s** |
| 4. | Pedon 4 | **S1** | **S1** | **S1** | **S2** | **S1** | **S1** | **S2** | **S1s** |
| 5. | Pedon 5 | **S1** | **S1** | **S2** | **S2** | **S1** | **S2** | **S1** | **S1s** |
| 6. | Pedon 6 | **S1** | **S1** | **S1** | **S2** | **S1** | **S3** | **S1** | **S1s** |
| 7. | Pedon 7 | **S1** | **S1** | **S1** | **S2** | **S1** | **S1** | **S1** | **S1s** |
| 8. | Pedon 8 | **S1** | **S1** | **S1** | **S2** | **S1** | **S3** | **S1** | **S1s** |
| | Pedon 9 | **S1** | **S1** | **S1** | **S2** | **S1** | **S3** | **S1** | **S1s** |

**Table 4.39 :Soil Suitability Class for crops**

| Soil unit | Soil Suitability Class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Wheat** | **Barley** | **Cotton** | **Oilseed (Raya)** | **Pearl millet** | **Pulses** | **Vegetable** | **Horticulture** | **Forestry** |
| **Pedon-1** | **S1** | **S1** | **S1** | **S1** | **S1** | **S2** | **S2** | **S1/S2** | **S1** |
| **Pedon-2** | **S1** | **S1** | **S1/S2** | **S1** | **S1** | **S2** | **S1/S2** | **S1** | **S1** |
| **Pedon-3** | **S1** | **S1** | **S1/S2** | **S1** | **S1** | **S2** | **S3** | **S2** | **S2** |
| **Pedon-4** | **S1** | **S1** | **S1/S2** | **S1** | **S1** | **S3/N** | **S2** | **S1** | **S1** |
| **Pedon-5** | **S1/S2** | **S1** | **S2** | **S1/S2** | **S2** | **S3/N** | **S2** | **S1** | **S2** |
| **Pedon-6** | **S1** | **S1** | **S2** | **S1** | **S2** | **S3** | **S2** | **S1** | **S2** |
| **Pedon-7** | **S1** | **S1** | **S2** | **S1/S2** | **S2** | **S3** | **S2** | **S1** | **S2** |
| **Pedon-8** | **S1** | **S1** | **S2** | **S1/S2** | **S2/S3** | **S3** | **S2** | **S1** | **S2** |
| **Pedon-9** | **S1** | **S1** | **S2** | **S1** | **S2/S3** | **S3** | **S2** | **S1** | **S2** |

The soils pedon 5 were placed in suitable class for barley, horticulture, and moderately to marginally suitable for wheat, pearl millet, cotton, Pulses, Vegetable and forestry. The soils pedon 6 were placed in suitable class for wheat, barley, oilseed, horticulture, and moderately to marginally suitable for pearl millet, cotton, Pulses, Pulses, Vegetable and forestry. The soils pedon 7, 8, 9 were placed in suitable class for wheat, barley, horticulture, and moderately to marginally suitable for pearl millet, cotton, Pulses, Pulses, Vegetable and forestry.

## CHAPTER-V

## DISCUSSION

The systematic characterization and classification of soils of an area is a need to explore the nature and extent of distribution of different kinds of soils their problems, potentials, capabilities and their suitability for various uses and sustained productivity. Therefore, in the present study, nine representative pedons were studied in experimental area of Department of soil science CCSHAU, Hisar Haryana. These pedons were examined morphologically in the field & physico-chemically in laboratory and classified as per keys to Soil Taxonomy (Soil Survey Staff, 2006). Land capability classes and sub-classes were also evaluated for these soils. Further, the suitability of these soils were evaluated for growing different crops. The results embodied in the previous chapter are discussed below.

### 5.1 Geomorphic-Soil Relationship

On the basis of various parameters *i.e.*, physiography, erosion, vegetation, topographical position, drainage in conjunction with ground truth the area is put under nearly levelled alluvial plane and their landform-soil relationship has been established. Pedon 1, 3, 6 and 9 had slight erosion, moderate drainage and good profile development. Pedon 2, 4 and 5 were levelled alluvial planes with well drained soils whereas pedon 7 and 8 were imperfectly drained with good profile development.

### 5.2 Morphological Characteristics

The soil colour is one of the important property among the morphological characteristics for identification of soils. The colour of the studied pedons varied from dark yellowish brown to yellowish brown with dominant hue of 10YR. The value ranged from 4 to 6, and chroma were 3 to 6. This variation in the soil colour was a function of textural makeup, topographic position, mineralogical, chemical composition and moisture regimes of the soil (Thangasamy *et al.,* 2005, Sahoo *et al.,* 2019).

In the study of genesis, classification and mapping, an accurate knowledge of morphology and texture of soils is imperative. Land use capability and methods of soil management are largely determined by texture (Kohnke, 1968). The soils of pedons 1, 2, 4, 8 and 9 were sandy loam on the surface and sandy clay loam in subsurface horizons in texture, due to variation in parent material and differential degree of weathering (Dinesh *et al*., 2017). Increase in clay content in sub surface horizon, then decrease in lower horizons showing the process of stratification and lithological discontinuity. Murthy (1988) and Nasre *et al*. (2013) reported that the clay content, by and large, increased with depth, which may be due to downward translocation of finer particles from the surface layers.

The pore spaces are as important in the soil as the solid particles, soil structure may also be defined as the arrangement of small, medium and large soil pores into a structural pattern (Kohnke, 1968). The structure of pedon 1, 3 and 5 was moderate, medium-sub angular blocky throughout the profile whereas Pedon 2, 4, 6, 7, 8, 9 exhibited moderate (surface and sub surface) to strong (lower depth), medium (surface and sub surface) to fine (lower depth), sub angular blocky structure. These results indicate that the variation in soil structure is the reflection of physiographic position of pedons, pedogenic activity, irrigation and cultivation practices of the soils (Singh and Aggarwal, 2003; Rao *et al*., 2008). Sharma *et al*. (1996) reported that the soil structure was relatively better developed in genetically well developed soils of alluvial plains, moderately developed in piedmont plains and flood plains whereas weakly developed in coarse strata.

Pedon 1and 9 were found slightly sticky, non-plastic on surface and slightly sticky, slightly plastic in consistency, due to light texture of the surface soil. The consistency, in general, was non-sticky non plastic which is indicative of poor water retention characteristics of the soils (Sharma *et al.,* 1993). The soils of pedon 2, 4 and 5 were found slightly sticky non-slightly plastic on the surface, sticky plastic on subsurface and slightly sticky, slightly plastic in lower horizons in consistency. The consistency of pedon 3, 6, 7 and 8 was observed slightly sticky slightly plastic (surface and sub-surface) and sticky plastic in lower horizons except pedon 7 which had very sticky very plastic consistency in lowermost. The variation in consistence was due to variation in texture of pedons.

Coarse fragments were absent in study area except pedons 1, 2 and 3 where it was present in sub-surface horizons varied from >1% ( pedon 1) and <1 in pedon 2 and 3. Calcium carbonate concretions were also present in pedons 1, 2 and 3. Slight to moderate effervescences were observed in pedons 1, 2, 3 and 4 predominantly in sub-surface horizons. The variation within the pedons may be considered to be inherent to the parent material. The possibility of in-situ formation of calcium carbonate may be due to calcification processes in some semi arid climatic conditions. Ahuja *et al*. (1997) also reported in sand dune topo-sequences of Haryana. In general, the roots were not well distributed throughout the pedons.

**5.3 Physical Properties**

Mechanical study of soil particles revealed that pedon subterranean horizons had higher clay content than surface horizons, possibly due to clay translocation and buildup (Fig. 5.16). Tripathi et al. (2006) discovered that sub-surface horizons included more clay than surface strata which they believe is due to the illuviation process that occurs during soil development. The vertical distribution of silt and sand contents is also affected by the illuviation process. Sand makes up the majority of the mechanical fractions (Fig. 5.14) due to the parent material's siliceous composition and the dominance of physical weathering. Because of their proximity to Rajasthan's desert areas, these places have a low proportion of silt (Fig. 5.15) in comparison to sand fractions, which is related to aeolian activity. (Ahuja and colleagues, 1997)

Water retention charatcers of horizons were shown to be highly linked to texture, with finer soil retaining more water and vice versa. In all of the pedons, water retention at field capacity and permanent wilting point ranged from 5.79 to 18.80% and 3.11 to 3.67%, respectively. Moisture retention at suctions 0.03 MPa and accessible water with clay were shown to have highly significant connections (Table 5.1). Clay and silt content of soil had a stronger effect on retention behaviour of different pedons than sand, according to correlation studies. The drainage that occurs when the suction pressure is increased from 0.03 to 1.5 Mpa could explain this. Because macro pores are emptied at lower suction levels and micro pores are emptied at higher suction levels, the effect of clay content manifests itself as a higher permanent wilting point due to the greater number of micro holes (Nikam et al., 2006). The coefficient of association between clay percentage and moisture retained at field capacity (0.03 MPa) ($r = 0.948$; p 0.01) and accessible water (0.935; p 0.01) was higher than that of organic carbon ($r = -0.405$ to -0.49), showing that an increase in clay boosted water retention. However, there was a strong negative association between accessible water content and sand ($r = -0.867$; p 0.01). This was because clay plays a large role in moisture retention. The influence of organic carbon was concealed by clay as organic carbon declined with depth while clay content increased in general. Balpande et al. (2007) reported similar findings. Furthermore, water retention and cation exchange capacity were shown to have a positive and significant association (Table 5.1), implying that clay mineralogy influences soil water retention characteristics since CEC is directly related to clay mineralogy. Lambooy also mentioned the influence of CEC on water retention (1984). As a result, in all pedons, silt and clay were discovered to be the primary contributors in regulating soil water content.

The infiltration rate obtained throughout the research was quite high (>1 cm $hr^{-1}$) in all of the pedons. The bulk density of the study area ranged from 1.38 to 1.62 Mg $m^3$, with an increasing trend with depth due to progressive compaction caused by eluvial materials filling pores, decreased organic matter, and less aggregation. Pedon 4, 6, 7 has a greater bulk density (>1.60 Mg $m^3$) due to reduced aggregation caused by the high sand content. Neto et al. (2015) found a greater bulk density (1.62-1.77 Mg $m^3$) in Brazilian floodplain soils, which they attributed to massive solid prismatic structures related with the soil's high silt content. Low organic matter and compaction of soil aggregates increased bulk density down the profile, according to Singh and Aggarwal (2005) and Kharlyngdoh et al. (2015). Singh et al. (1993) observed similar findings when examining the pedogenesis and taxonomy of soils in a toposequence of the central Himalayas. The particle density and total porosity varied from 2.45 to 2.64 Mg $m^{-3}$ and 34.29 to 47.96 percent, respectively and did not show any trend with depth.

### 5.4 Chemical Characteristics

The pH of the soil is an important chemical property as it impacts the capacity for plant growth, nutrient availability, soil physical condition and microbial activity. The pH of soil samples in examined soils ranged from 7.5 to 8.5, indicating a slightly alkaline to moderately alkaline in reaction according to pH classifications defined by Soil Survey Staff (2006). The non-saline nature of the soils was shown by the electrical conductivity of all the pedons. It is owing to the sandy nature of the land and agricultural techniques that do not use irrigation. Similar results regarding non-saline nature of soils in various arid and semiarid regions of India, were reported by Sehgal et al. (1986). Similarly, while studying the soils of the western Shiwalik Himalayas in Punjab, Sharma et al. (2011) discovered low electrical conductivity.

Organic carbon levels in the study soils were low. All of the pedons' soils had organic carbon levels ranging from 0.06 to 0.27 percent. The low organic carbon content of these pedons, which declined with depth, may be due to a fast rate of organic matter decomposition under hyperthermic temperature, which results in very high oxidising conditions (Singh et al., 2014; Bhat et al., 2017). The low organic carbon content could also be attributed to differences in vegetation colonisation, an aridic moisture regime, minimal rainfall and poor vegetation. The low concentration of organic carbon in dunal soils was also noted by Ahuja et al. (1997). Silmilarly, Veeresh et al., (2016) and Sawhney et al., (2000) found a reduction in organic carbon with depth in the Yagdir district of Karnataka and the south-eastern sector of the Punjab sub-montane tract, respectively.

These soils were non-calcareous to somewhat calcareous. Except for pedon 5, calcium carbonate concretions were not found in the pedons 1, 4, 8, or at the surface horizons of any of the pedons. The lack of calcium carbonate in sand dunal soils suggested that non-calcareous sediments had been transported and deposited there. Because of the calcareous sediments that were carried and deposited by fluvial activity, greater amounts of $CaCO^3$ were found at lower depths in pedons 2, 3, 5, 6, and 7, ranging from 0.23 to 11.73 percent and also rising trend with the depth. The probability of *in situ* CaCO3 generation in these soils due to calcification and aridic climatic conditions cannot be discounted. The percentage of calcium carbonate concretions found in the pedon-7 subsurface horizons ranged from 5.25 to 10.75 percent. Ahuja et al. in 1997 also documented evidence in favour of similar actions. Furthermore, nodulation was not present, which could be attributable to a lack of calcium carbonate enrichment in the sediment.

The examined pedons had a low cation exchange capacity (3.82 to 7.85 cmol (p+) $kg^{-1}$), which might be attributed to the sandy nature of the soil and its low clay and organic carbon content. The prevalence of illite and other low charge minerals, as well as low organic matter concentration, contribute in these soils' low cation exchange capacity (Sharma et al., 2011; Dinesh et al., 2017). Soil CEC and clay (r=0.822; p0.05) and silt (r=0.456; p0.05) had a substantial positive connection (Table5.2) indicated that clay and silt were the main factors influencing CEC. Karmakar (2014) discovered a positive and substantial link between CEC and clay and silt, indicating that the silt fraction carries sufficient negative charge, which could be owing to weathering or finer silt fractions less than 0.002 mm. As a result of changes in soil depth and topographic position, the exchangeable bases showed a variety of regular and irregular tendencies. Calcium was the most abundant exchangeable cation in all pedons (2.10 to 5.10 cmol (p+) $kg^{-1}$), followed by magnesium (0.20 to 2.90 cmol (p+) $kg^{-1}$), sodium (0.19 to 0.92 cmol (p+) $kg^{-1}$), and potassium (0.08 to 0.42 cmol (p+) $kg^{-1}$). Sharma et al. (2011) found similar results in the Western Shiwalik Himalayas. All of the pedons studied had non-sodic soils, with the exception of pedon 8's Ap horizon, which had ESP 15.08 percent (ESP; 3.88 to 15.08 percent). Base saturation percentages (BSP) ranged from 88.36 to 98.57 which dominated the exchangeable complex. The base saturation of exchangeable complexes is high due to the presence of cations with adequate exchangeable $Ca^{2+}$. According to Sharma et al. (2004), the difference in cation exchange capacity, base saturation, and water retention percentages amongst soils can be attributed in part to the different type/content of soil colloids and soil pH values.

Soil fertility demonstrates the importance of various soils in terms of the amount and availability of essential components for plant growth (Sarkar et al., 2002). Available nitrogen was low among the macronutrients, ranging from 42 to 189 kg $ha^{-1}$. The available nitrogen was highest in the upper layers and reduced as one progressed down the profile, which may be explained by the decreasing trend of organic carbon with depth and the high temperature. The results showed a significant and positive association between available nitrogen and organic carbon, implying that nitrogen is tightly linked to organic matter ($r = 0.888$; $p \leq 0.01$). According to Meysner et al. (2006), organic matter is responsible for 93 to 97 percent of total nitrogen in soils. According to Hailu et al. (2015), total N trends in general followed that of soil OM, indicating a strong association between OM and total N as seen by the positive and highly significant (r = 0.85; p 0.01) correlation with OM. N and P (r = 0.717; p0.01), as well as N and K (r = 0.700; p 0.01), had a positive and significant correlation, implying synergistic effects.

In the examined pedons, accessible phosphorous ranged from 4.2 to 17.10 kg $ha^{-1}$ and was generally low to medium. Ordinarily, accessible phosphorous decreased down the profile which could be due to a rise in clay content and all these ultimately resulted in phosphorus fixation. Available phosphorous and organic carbon have a substantial positive connection (r = 0.885; p0.01), implying that more available P is connected with more organic matter. Organic matter increases P by replacing the $H_2PO_4$ ion on adsorption sites with an anion, resulting in an increase in the amount of organic P mineralized to inorganic P. (Havlin et al.

2005; Bhat et al., 2017). The potassium availability in soils ranged from 62.2 to 326.5 kg $ha^{-1}$ (Fig. 5.9). These nutrients showed a decreasing tendency from surface to subsurface horizons with depth. Because of the presence of potassium bearing minerals like feldspars, illite, and mica in clay and silt fractions, the correlation analysis shows that available K has a positive and significant correlation with organic carbon (r = 0.556; p0.01), positive correlation with clay (r = 0.046), and positive correlation with silt (r = 0.023). (Deka et al., 1995; Reza et al., 2014). Available K, on the other hand, was inversely linked with sand (r = -0.041), which could be owing to the presence of quartz, which is the major mineral in the sand fraction and does not retain K, confirming findings of Reza et al's (2014).

The Zn content of DTPA extractables ranged from 0.15 to 0.92 mg $kg^{-1}$ (Fig. 5.10). Given the threshold limit of DTPA extractable Zn for normal plant growth of 0.6 mg $kg^{-1}$ (Lindsay and Norvell, 1978), all soils were low in Zn content. The Fe content of DTPA extractables ranged from 0.87 to 6.49 mg $kg^{-1}$ (Fig. 5.11). Given the threshold limit of DTPA extractable Fe for proper plant growth of 4.5 mg $kg^{-1}$ (Lindsay and Norvell, 1978), soils in the research area were, on the whole, low in Fe concentration. The soil Cu content in DTPA extractables ranged from 0.13 to 0.72 mg $kg^{-1}$ (Fig. 5.13). Using the threshold limit of DTPA extractable Cu for normal plant growth of 0.2 mg $kg^{-1}$ (Lindsay and Norvell, 1978), it can be inferred that all soils have a high Cu content. The Mn concentration of DTPA extractables ranged from 1.03 to 4.99 mg $kg^{-1}$ (Fig. 5.12). Using 1 mg $kg^{-1}$ as the critical limit of DTPA extractable Mn for normal plant growth (Lindsay and Norvell, 1978), it was determined that all soils had a high Mn content.  The presence of ferromagnesium minerals in parent material may explain the high Fe and Mn content in soils. Simple correlation analyses reveal a substantial negative connection (p0.01) between available Fe and Mn and pH (r = -0.513 and r = -0.569, respectively), which could be attributable to $Fe^{2+}$ to $Fe^{3+}$ conversion or Fe precipitation as insoluble $Fe(OH)_2$. This may be due to the conversion of manganous Mn to manganic oxides, which are water impermeable and unavailable to plants in the case of Mn (Vijayakumar et al., 2011; Baruah et al., 2014). Furthermore, there was a positive and substantial association between the micronutrients, implying that these elements are functions of the same pedological determinants, confirming the findings of the previous study Verma *et al*. (2006). Soil Fertility maps of the experimental farm have also been repared fig: 5.15 – 5.21.

**5.5 Soil Classification**

The soil is a body of minerals, organic matter, liquid and gases that is able to support rooted vegetation in a natural environment or that is characterized by horizons or layers that are distinguishable from the initial material as a result of pedogenesis (Soil Survey Staff, 2006). The soils of studied pedons were classified in accordance with USDA Soil Taxonomy (Soil Survey Staff, 2006). Owing to variation in morphology, physico-chemical characteristics, the soils of the study area were classified into different units. On the basis of rainfall and evaporation these soils were grouped in Ustic (rainfall 300-1000mm) moisture regimes. Based on soil temperature and mixed minerals the soils were placed under hyperthermic and mixed mineralogy family, respectively.

The soils of the studied area were placed under the order Inceptisols which have pedogenic development and horizon differentiation. There was a variation in particle size distribution in surface and sub surface these soils were classified as Coarse/Fine loamy family. The landform - Soil Taxonomy relationship has also been reported by Ahuja *et al.* (1997) for desert soils of Haryana and Dinesh *et. al*. (2017) in North Eastern part of Haryana.

**5.6 Land Evaluation**

Land evaluation is a multi-disciplinary approach. Land suitability is assessed and classified with respect to the specific type of use during land evaluation. The suitable qualitative land evaluation procedures for conservation of land resources includes land capability classification, soil suitability classification for irrigation and crops.

The land capability classification is an interpretation grouping of various soil units that helps with land use planning. The results revealed (Table 4.37) that due to the limitations of texture, cation exchange capacity and organic carbon, the soils were classed as Ids and Is according to Land Capability Classification. The soils of pedon 1 and 3 were put under LCC class Ids due to low fertility status, drainage and less cation exchange capacity. Rest of the soils were placed in LCC class Is due to low fertility and less cation exchange capacity problems. Devi and Naidu (2016) classify the sugarcane soil of Chittoor, AP into land capability class 4s due to major limitation of texture, organic carbon and base saturation percentage.

The soils experimental area was evaluated for irrigability classification based on the land qualities given by Frame work of Land Evaluation (FAO, 1993). The results presented in Table 4.38 inferred that all the pedons are put under S1s. The results are in conformity with those of Nagaraju *et al*. (2014).

The soil suitability rating for different crops were evaluated and presented in Table 4.39. The soils of pedon 1 and 2 were suitable for wheat, barley, cotton, pearl millet, forestry, oilseed (Raya) and moderately to marginally suitable for Pulses, Pulses, horticulture and Vegetable. The soils pedon 3 were placed in suitable class for wheat, barley, Oilseeds, pearl millet and moderately to marginally suitable for forestry, Pulses, Horticulture and Vegetable. The soils pedon 4 were placed in suitable class for barley, pearl millet, forestry, horticulture, oilseed (Raya) and moderately to marginally suitable for Pulses, and Cotton.The soils pedon 5 were placed in suitable class for barley, horticulture, and moderately to marginally suitable for wheat, pearl millet, cotton, Pulses, Pulses, Vegetable and forestry. The soils pedon 6 were placed in suitable class for wheat, barley, oilseed, horticulture, and moderately to marginally suitable for pearl millet, cotton, Pulses, Pulses, Vegetable and forestry. The soils pedon 7, 8, 9 were placed in suitable class for wheat, barley, horticulture, and moderately to marginally suitable for pearl millet, cotton, Pulses, Pulses, Vegetable and forestry. Similar findings were also reported by Mustafa *et. al*., (2016), Dinesh *et. al*., (2017) and Sahoo *et. al*., (2020).

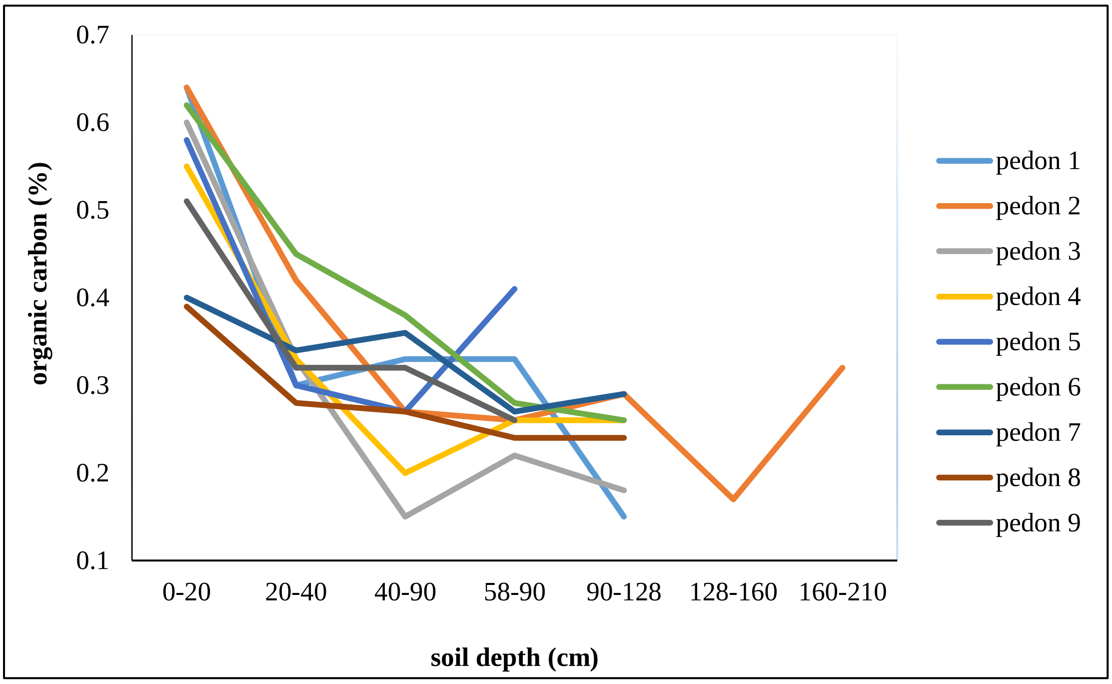



**Fig. 5.1 Vertical distribution of organic carbon in different pedons**

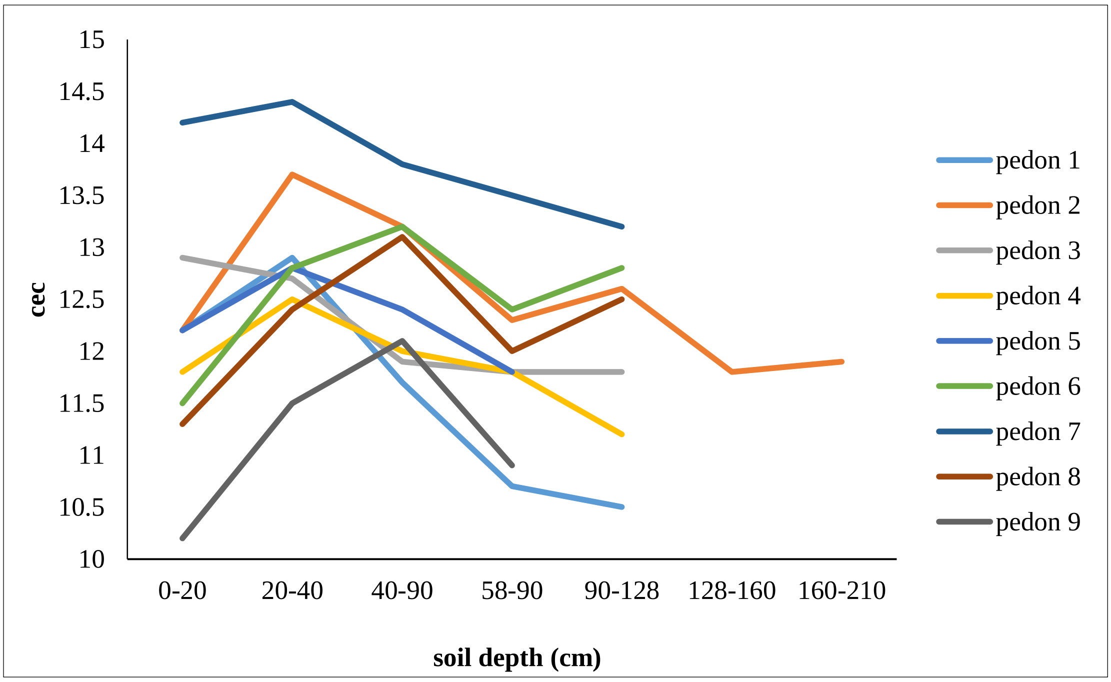



**Fig. 5.2 Vertical distribution of cation exchange capacity in different pedons**

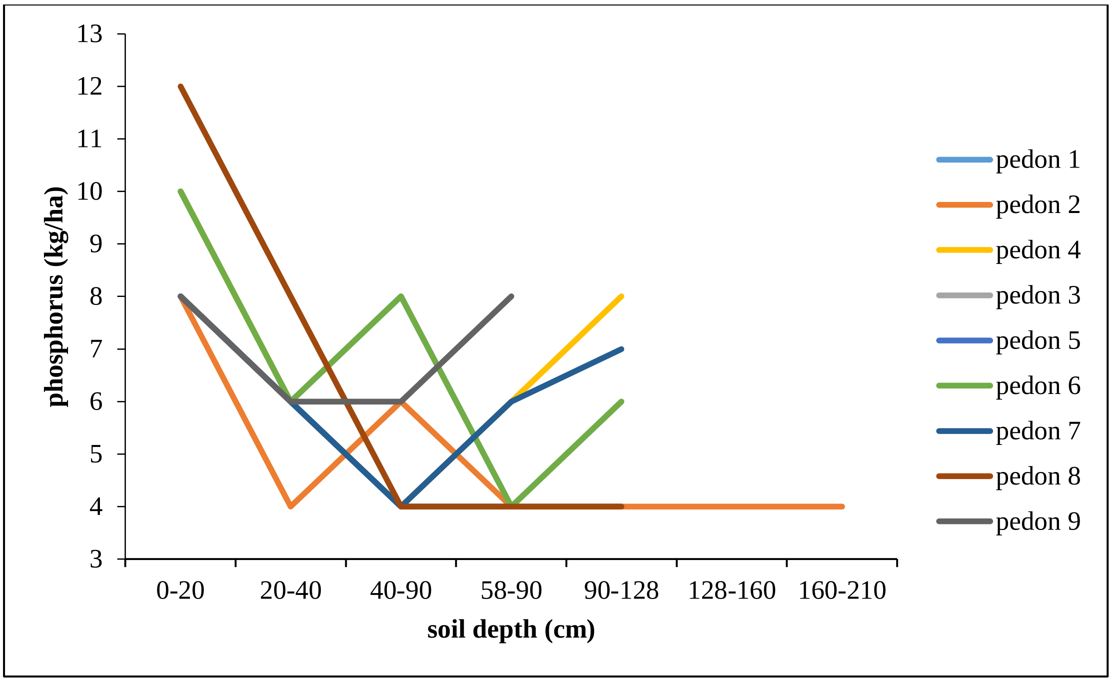



**Fig. 5.3 Vertical distribution of nitrogen in different pedons**

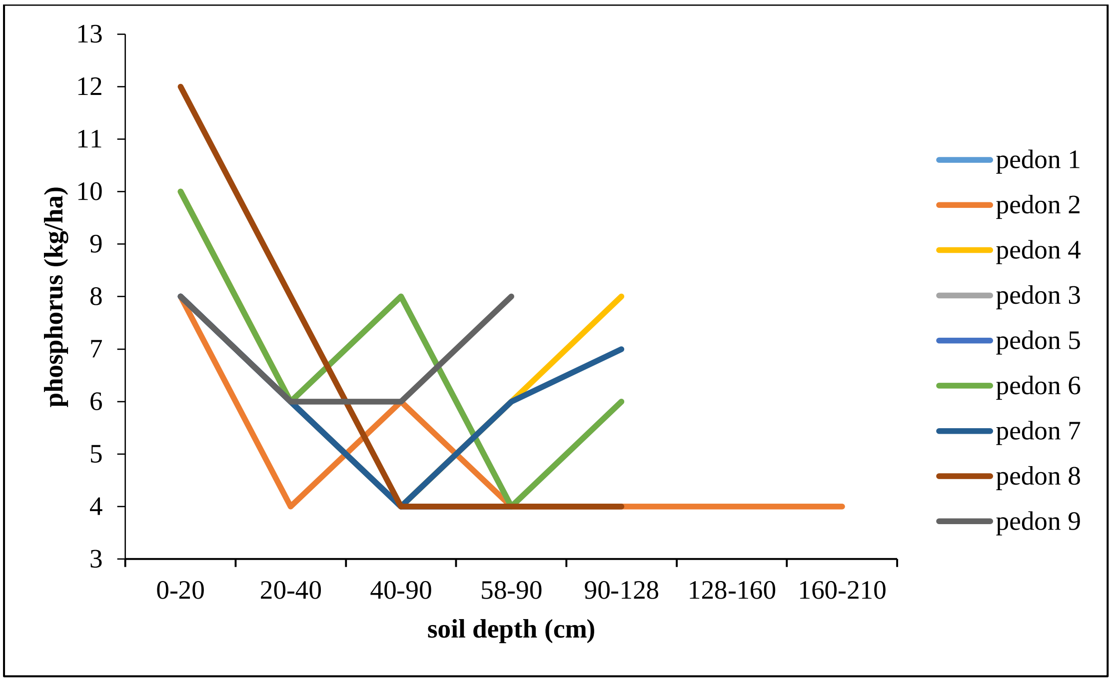



**Fig. 5.4 Vertical distribution of phosphorous in different pedons**

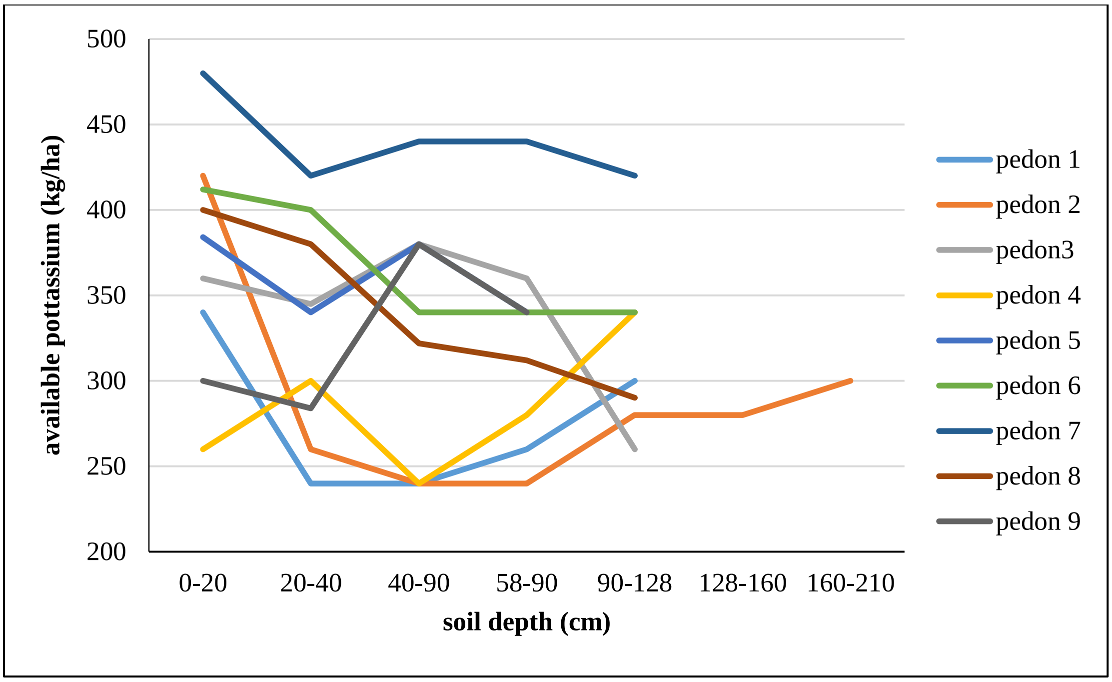



**Fig. 5.5 Vertical distribution of potassium in different pedons**

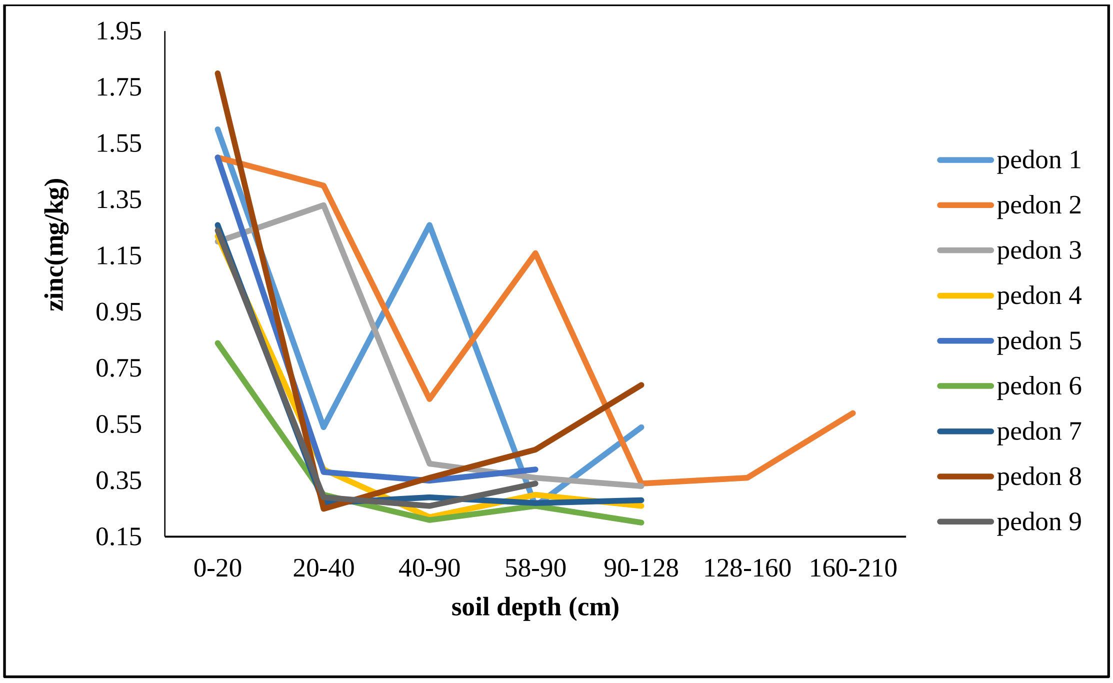



**Fig. 5.6 Vertical distribution of zinc in different pedons**

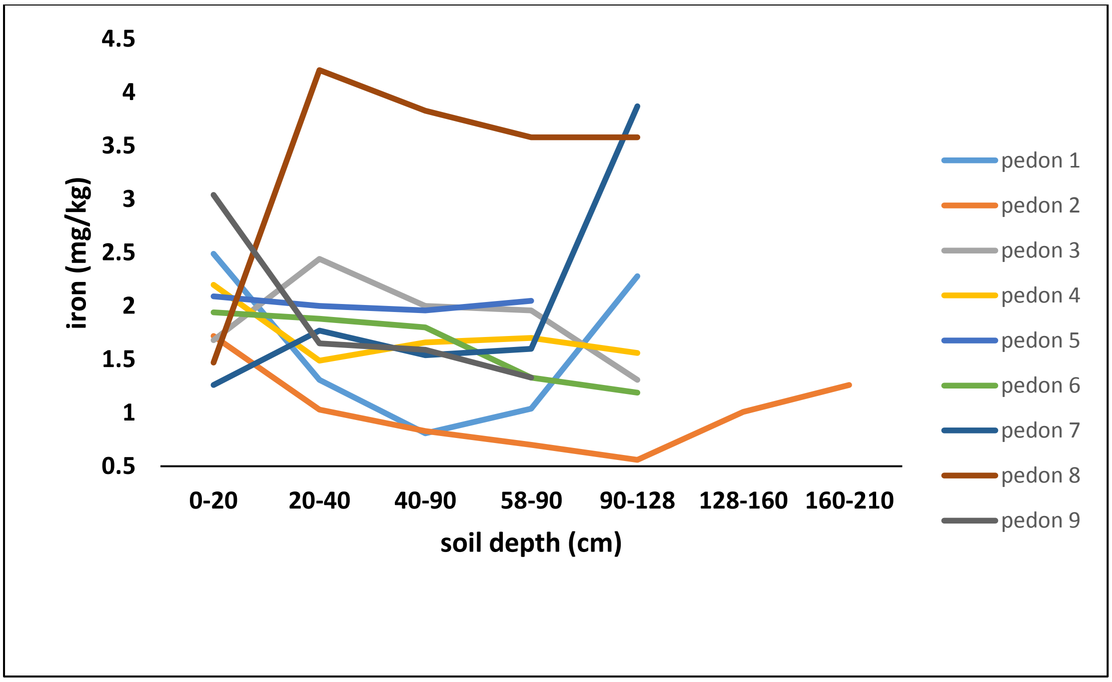



**Fig. 5.7 Vertical distribution of Iron in different pedons**

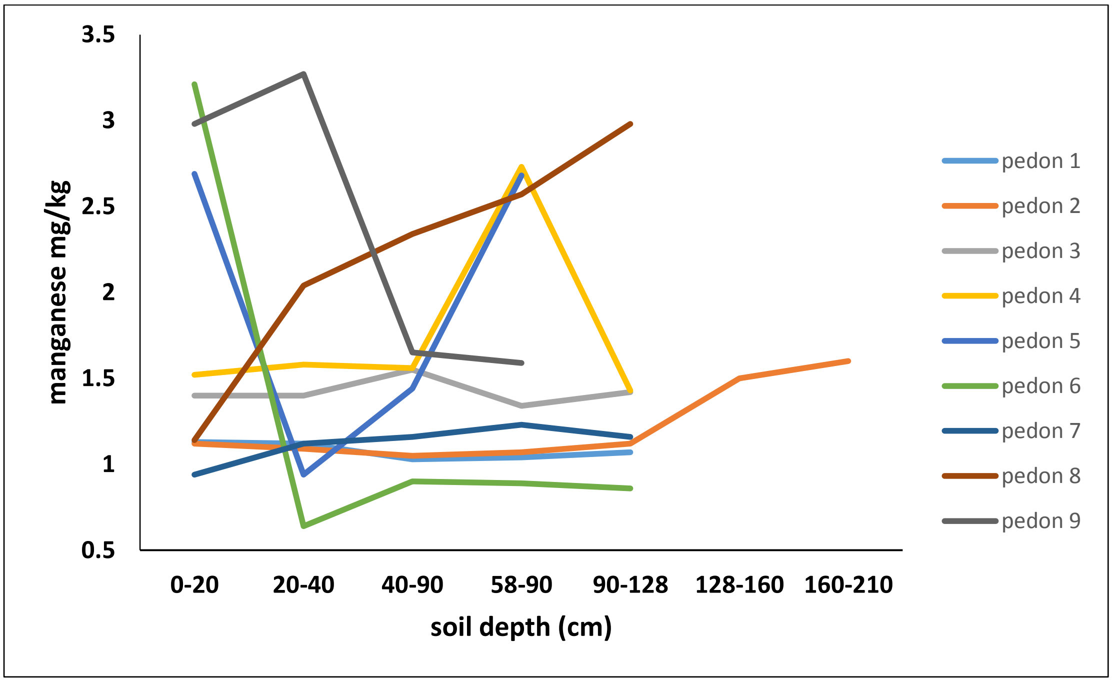



**Fig. 5.8 Vertical distribution of manganese in different pedons**

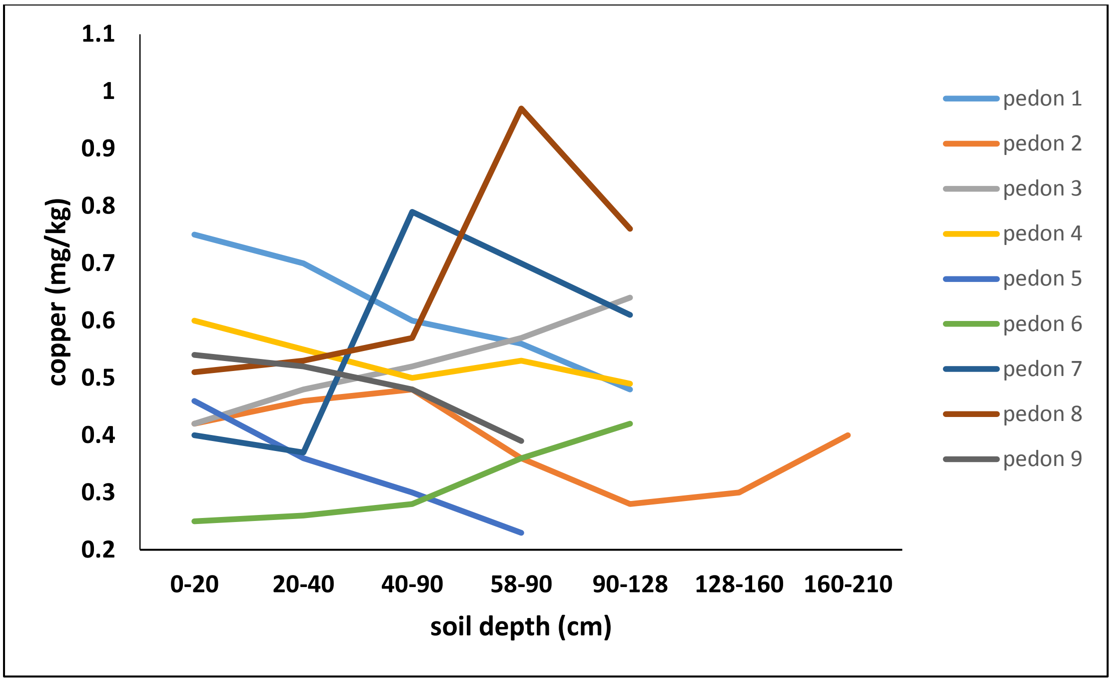



**Fig. 5.9 Vertical distribution of copper in different pedons**

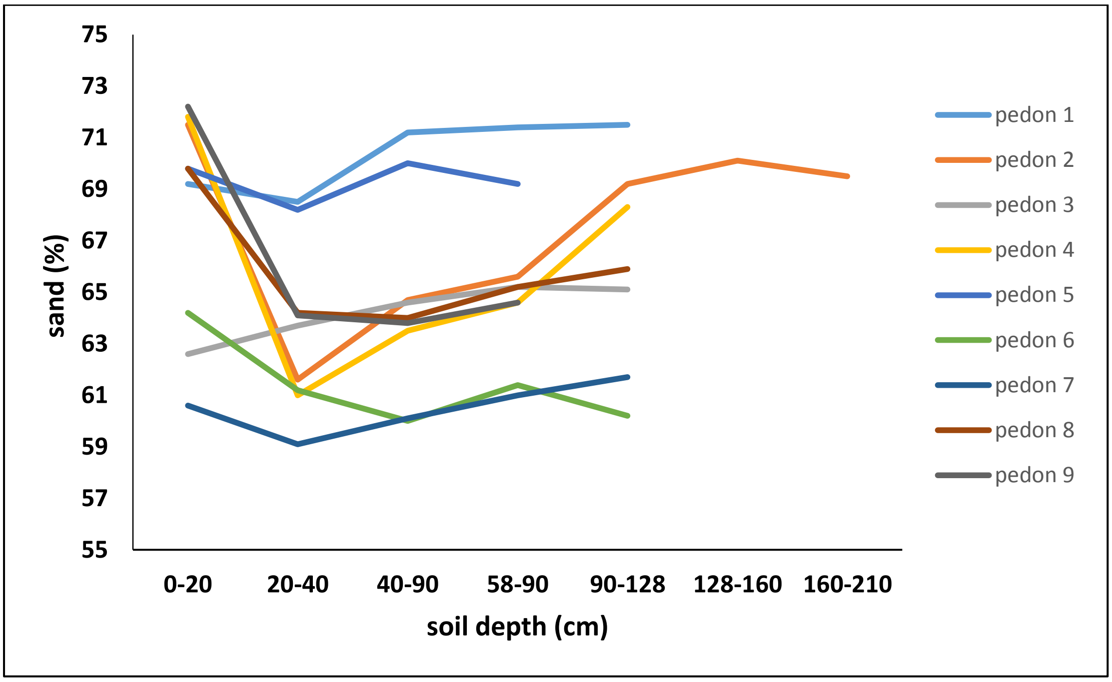



**Fig. 5.10 Vertical distribution of sand in different pedons**

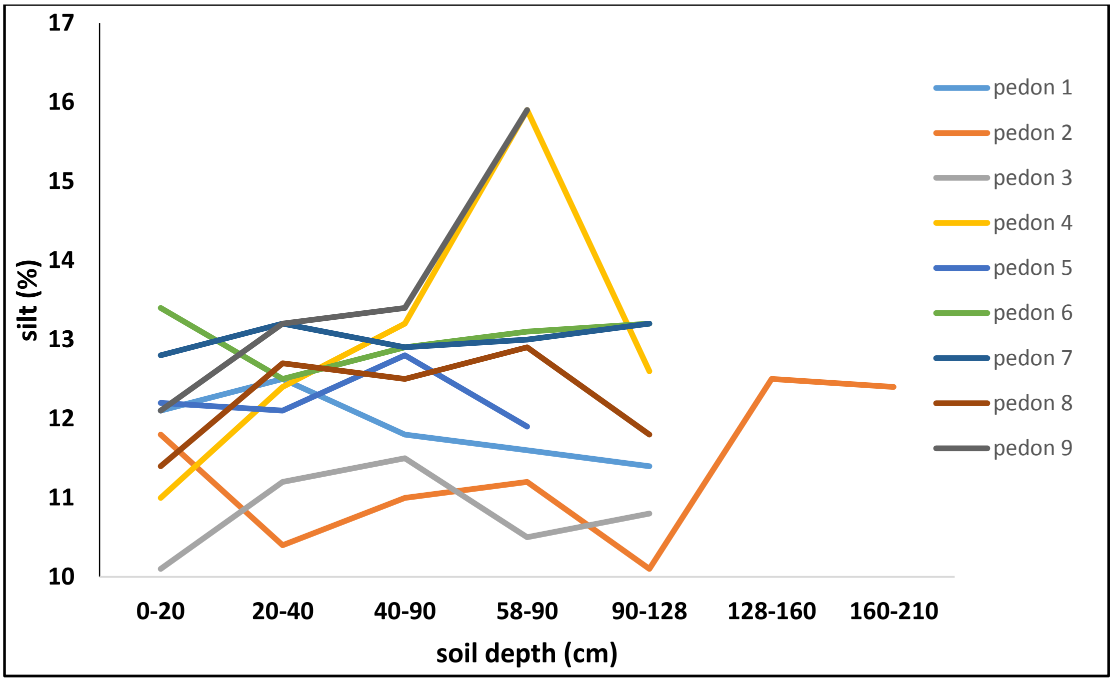



**Fig. 5.11 Vertical distribution of silt in different pedons**

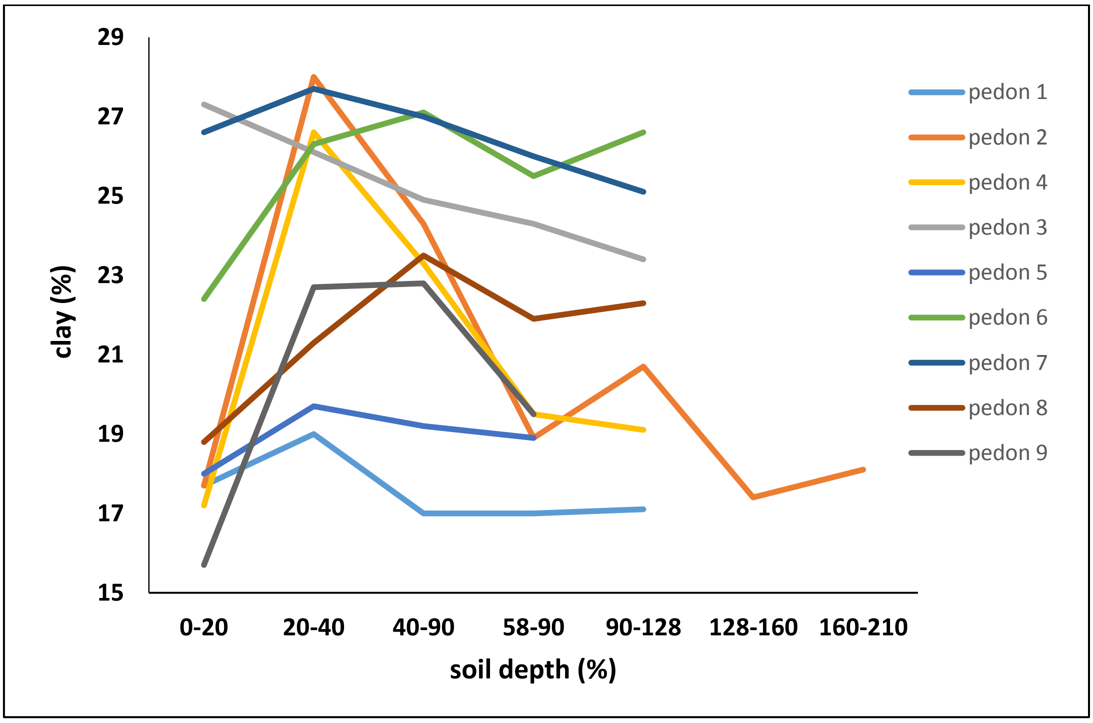



**Fig. 5.12 Vertical distribution of clay in different pedons**

**Table 5.1: Correlation matrix among physico-chemical properties**

| PARAMETER | | Sand (%) | Silt (%) | Clay (%) | BD | PD | PS | Moisture retention | | Available water (%) | OC (%) | CEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | (0.03 MPa) | (1.5 MPa) | | | |
| Sand (% | | 1 | | | | | | | | | | |
| Silt (%) | | -0.941** | 1 | | | | | | | | | |
| Clay (%) | | -0.781** | 0.672* | 1 | | | | | | | | |
| BD | | 0.386 | -0.348 | -0.269 | 1 | | | | | | | |
| PD | | 0.348 | -0.538 | 0.072 | 0.289 | 1 | | | | | | |
| PS | | -0.234 | 0.192 | 0.236 | -0.947** | 0.146 | 1 | | | | | |
| Moisture retention | 0.03 MPa | -0.871** | 0.675 | 0.981** | -0.331 | -0.024 | 0.263 | 1 | | | | |
| | 1.5 MPa | -0.522 | 0.338 | 0.669 | -0.518 | 0.358 | 0.618 | 0.795* | 1 | | | |
| Available water (%) | | -0.815** | 0.718* | 0.917** | -0.241 | -0.179 | 0.113 | 0.922** | 0.564 | 1 | | |
| OC (%) | | 0.186 | -0.124 | -0.179 | 0.271 | 0.242 | -0.173 | -0.471 | -0.593 | -0.399 | 1 | |
| CEC | | -0.741* | 0.795* | 0.712* | -0.465 | -0.224 | 0.386 | 0.739* | 0.678 | 0.762* | -0.610 | 1 |

** Significant at 0.01 probability level

* Significant at 0.05 probability level

**Table 5.2: Correlation matrix among physico chemical properties**

| Parameter | pH | EC | OC | $CaCO_3$ | CEC | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | $K^+$ | ESP | BSP | sand | silt | clay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | 1 | | | | | | | | | | | | | |
| EC | 0.566** | 1 | | | | | | | | | | | | |
| OC | -0.469** | -0.224 | 1 | | | | | | | | | | | |
| $CaCO_3$ | 0.498** | 0.468** | -.404* | 1 | | | | | | | | | | |
| CEC | 0.245 | 0.249 | -.359* | 0.341* | 1 | | | | | | | | | |
| $Ca^{2+}$ | -0.063 | -0.169 | -0.271 | 0.374 | 0.612** | 1 | | | | | | | | |
| $Mg^{2+}$ | 0.384* | 0.526** | -0.112 | 0.189 | 0.541** | -0.267 | 1 | | | | | | | |
| $Na^+$ | 0.165 | 0.049 | -0.289* | 0.141 | 0.397* | 0.447** | -0.175 | 1 | | | | | | |
| $K^+$ | -0.376* | -0.194 | 0.345* | -0.327 | -0.065 | -0.267 | 0.164 | -0.446** | 1 | | | | | |
| ESP | 0.072 | -0.046 | -0.271 | 0.086 | 0.048 | 0.284 | -0.335* | 0.964** | -0.474** | 1 | | | | |
| BSP | -0.183 | -0.117 | 0.176 | -0.034 | -0.176 | 0.197 | -0.286 | 0.074 | -0.184 | 0.146 | 1 | | | |
| sand | -0.075 | -0.084 | 0.223 | -0.548** | -0.645** | -0.442** | -0.349* | -0.213 | 0.021 | 0.111 | 0.345* | 1 | | |
| silt | 0.098 | 0.156 | -0.194 | 0.549** | 0.488** | 0.204 | 0.271 | 0.174 | -0.095 | -0.078 | -0.361* | -0.878** | 1 | |
| clay | 0.062 | -0.121 | -0.346* | 0.374* | 0.874** | 0.674** | 0.287 | 0.191 | 0.178 | -0.179 | -0.234 | -0.813** | 0.491** | 1 |

** Significant at 0.01 probability level

* Significant at 0.05 probability level

**Table 5.3: Correlation among nutrients and physico-chemical properties**

| Parameter | N | P | K | Zn | Fe | Mn | Cu | OC | pH | Sand | Silt | Clay |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | 1 | | | | | | | | | | | |
| P | 0.726** | 1 | | | | | | | | | | |
| K | 0.685** | 0.396* | 1 | | | | | | | | | |
| Zn | 0.294 | -0.153 | 0.456** | 1 | | | | | | | | |
| Fe | 0.412** | -0.229 | 0.629** | 0.488** | 1 | | | | | | | |
| Mn | 0.255 | -0.205 | 0.596** | 0.452** | 0.659** | 1 | | | | | | |
| Cu | 0.246 | -0.255 | 0.458** | 0.643** | 0.676** | 0.565** | 1 | | | | | |
| OC | 0.895** | 0.824** | 0.524** | 0.011 | 0.129 | 0.096 | 0.044 | 1 | | | | |
| pH | -0.499** | -0.074 | -0.596** | -0.423** | -0.555** | -0.545** | -0.408* | -0.398* | 1 | | | |
| Sand | 0.288 | 0.246 | -0.092 | -0.145 | 0.139 | -0.275 | -0.113 | 0.225 | -0.099 | 1 | | |
| Silt | -0.193 | -0.102 | 0.051 | -0.055 | -0.222 | 0.092 | -0.074 | -0.114 | 0.176 | -0.915** | 1 | |
| Clay | -0.291 | -0.344* | 0.092 | 0.286 | 0.028 | 0.288 | 0.349* | -0.369* | 0.056 | -0.775** | 0.435** | 1 |

** Significant at 0.01 probability level

* Significant at 0.05 probability level

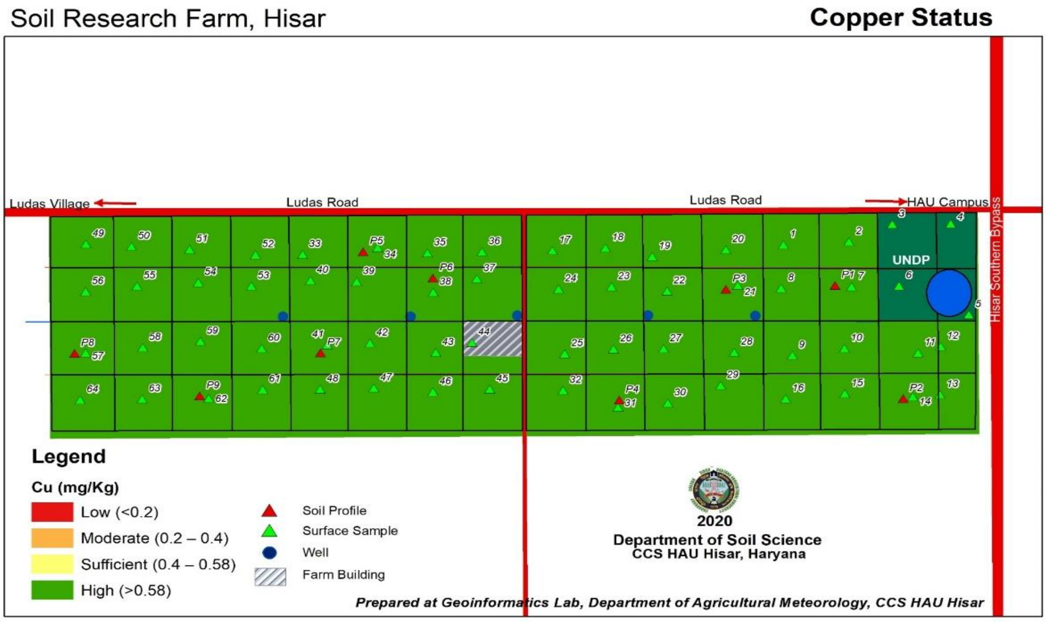



**Fig:5.13. Chart of copper status in soil research farm**

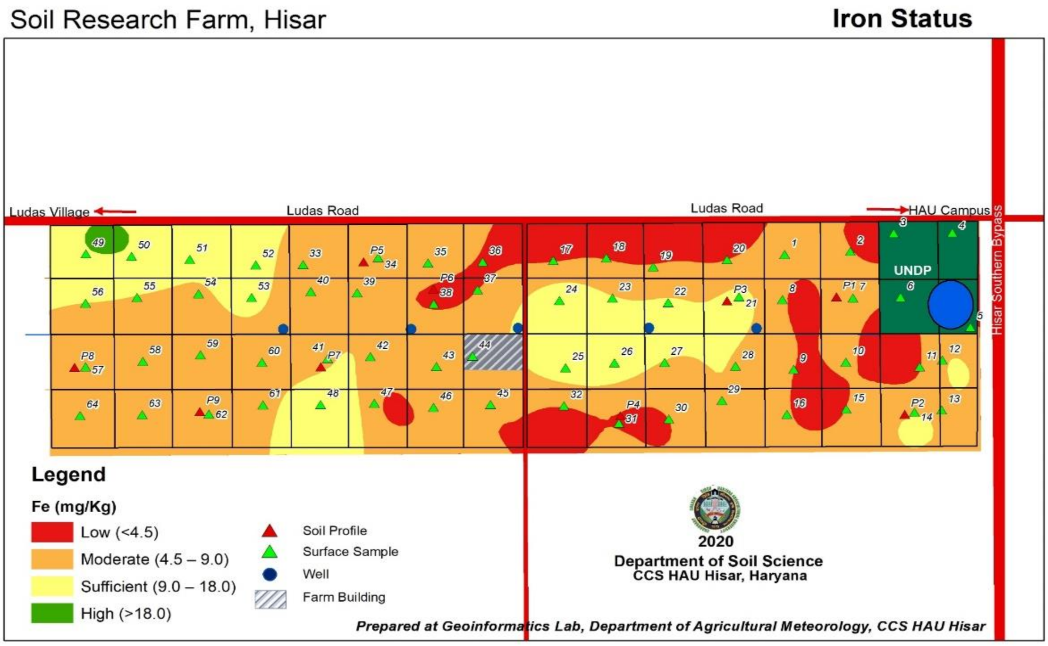



**Fig:5.14. Chart of iron status in soil research farm**

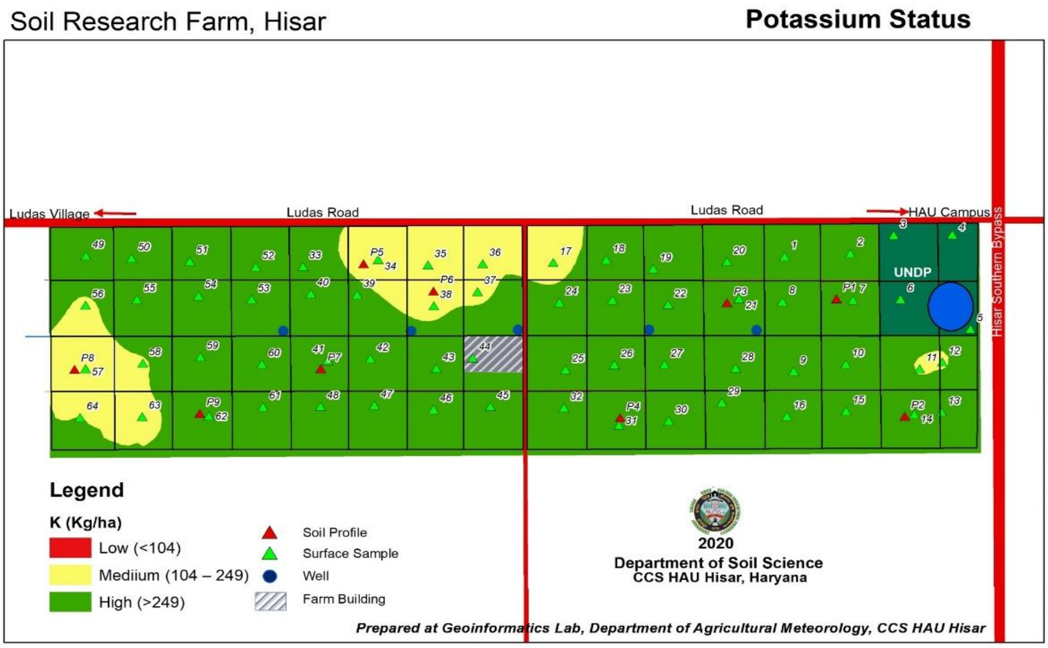



**Fig:5.15. Chart of potassium status in soil research farm**

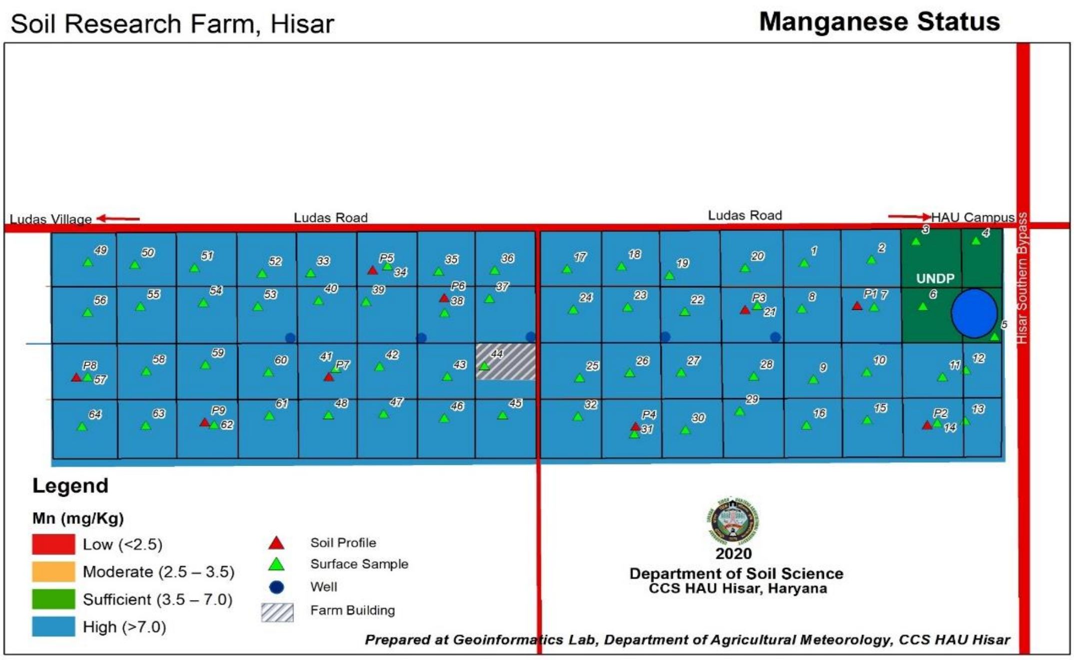



**Fig:5.16. Chart of manganese status in soil research farm**

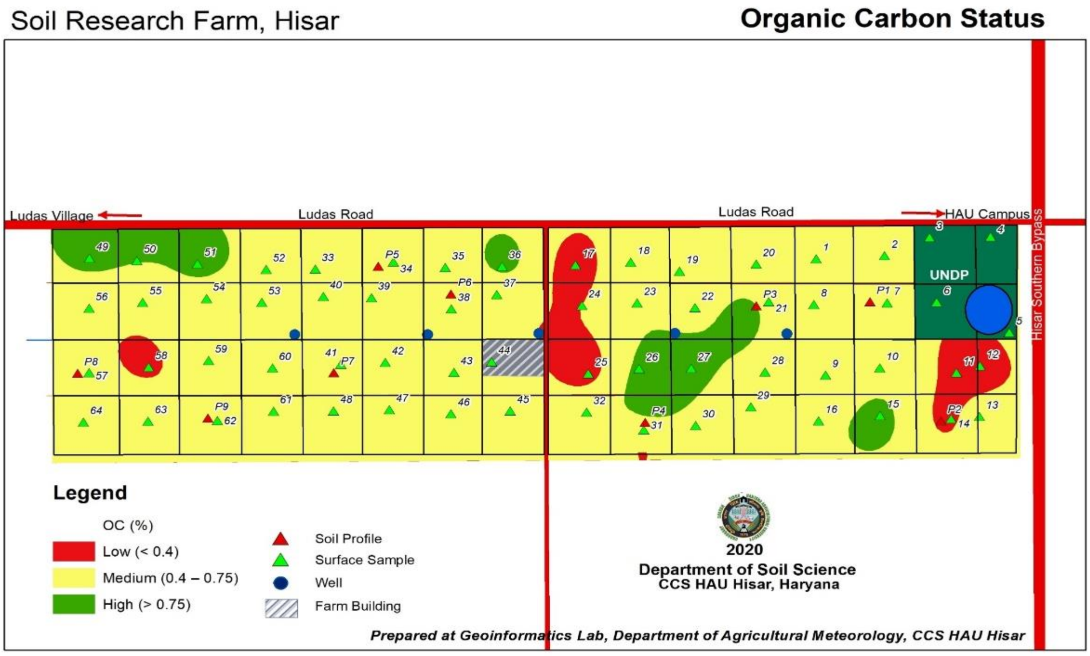



**Fig:5.17. Chart of organic carbon status in soil research farm**

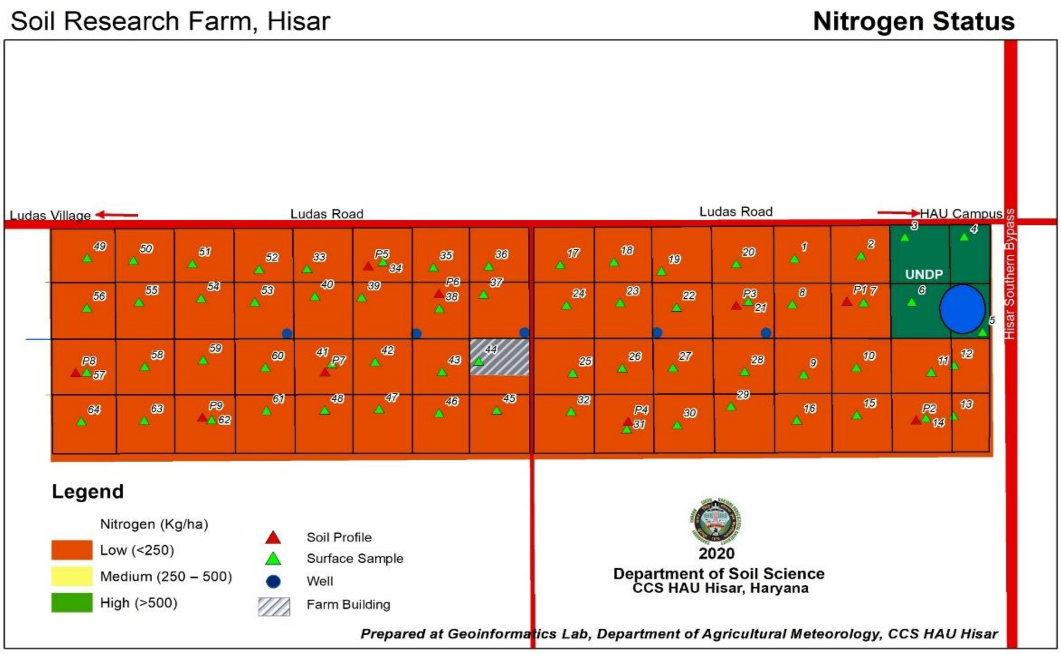



**Fig: 5.18. Chart of nitrogen status in soil research farm**

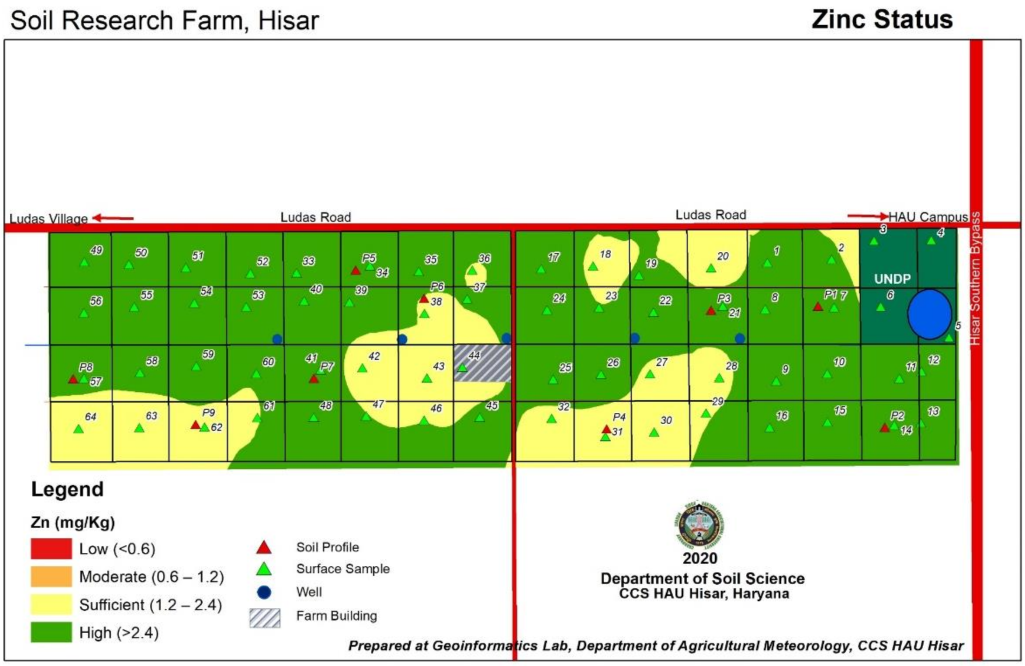



**Fig: 5.19. Chart of zinc status in soil research farm**

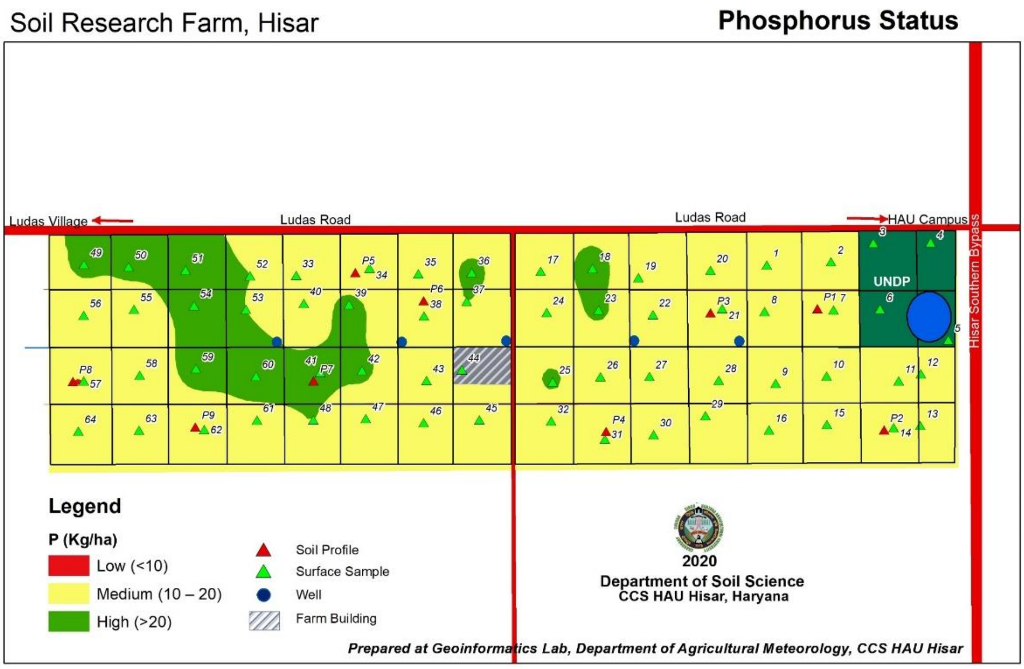



**Fig: 5.20. Chart of phosphorus status in soil research farm**

CHAPTER-VI

# SUMMARY AND CONCLUSION

A study on "**Characterization and Classification of Soil properties of Soil Research Area at CCSHAU, Hisar**" was carried out. Visual interpretation of IRS-P6 satellite imagery (FCC) of 1:50000 scales used for the preparation of base map of the area. The area traversed thoroughly for field checked and the profile sites were delineated. Nine soil profiles were exposed and studied morphologically in field by using FAO guidelines for soil profile description. The soil samples from each profile were collected horizon-wise.

All the studied pedons were very deep (150+ cm). The colour of the pedons varied from dark yellowish brown to yellowish brown with dominant hue of 10YR. The value ranged from 4 to 6, and chroma were 3 to 6. The soils of the experimental area were sandy loam on the surface and sandy clay loam in subsurface horizons in texture, due to variation in parent material and differential degree of weathering. Increase in clay content in sub surface horizon, then decrease in lower horizons showing the process of stratification and lithological discontinuity.The structure of pedons was moderate, medium to fine sub angular blocky throughout the profile whereas in some pedons exhibited moderate (surface and sub surface) to strong (lower depth), medium (surface and sub surface) to fine (lower depth), sub angular blocky structure may be due to the reflection of physiographic position of pedons, pedogenic activity, irrigation and cultivation practices of the soils. Pedon 1and 9 were found slightly sticky, non-plastic on surface and slightly sticky, slightly plastic in consistency, due to light texture of the surface soil, pedon 2, 4 and 5 were found slightly sticky non-slightly plastic on the surface, sticky plastic on subsurface and slightly sticky, slightly plastic in lower horizons in consistencyand pedon 3, 6, 7 and 8 was observed slightly sticky slightly plastic (surface and sub-surface) and sticky plastic in lower horizons except pedon 7 which had very sticky very plastic consistency in lowermost. The variation in consistence was due to variation in texture of pedons.

Bulk density of study area ranged between 1.59 and 1.43 Mg $m^{-3}$ showing the increasing trend with the depths. This may be due to progressive compaction appertaining to filling of pores with eluvial materials, lower organic matter and lower aggregation. The particle density of different pedons ranged between 2.81 and 2.99 Mg $m^{-3}$. The pore space of 1the studied pedons ranged between 48.0 and 57.19. Moisture content at field capacity and permanent wilting point varied from 16.1 to 21.8% and 6.0 to 8.0%, in all the pedons respectively. Moisture content at suctions of 0.03 MPa and accessible water with clay were shown to have quite significant connections. Clay and silt content had a stronger effect on retention behaviour of different pedons than sand according to correlation studies.

The soils are neutral to slightly alkaline pH (6.4 to 8.3) except in pedon 8 in reaction. The electrical conductivity of all the pedons indicated that the soils were non- saline (0.16 to 0.37 ds $m^{-1}$) in nature. The different pedons of the studied area had reduced electrical conductivity at the surface, while deeper horizons had no discernible pattern.These soils were non-calcareous to slightly calcareous. The calcium carbonate in the soil in different pedons range from 0.4 to 1.6 per cent (pedon 1, 2 ,3 ,4) and it was totally absent the soils of the pedons 5, 6, 7, 8 and 9.

The cation exchange capacity was low [10.6 to 14.4 cmol $(p^+)$ $kg^{-1}$]. This could be attributed to soil texture and its low clay and organic carbon content in the examined pedons. A significant correlation coefficient between clay and CEC suggested that clay contributed to the quantity of CEC in these soils. Among exchangeable cations calcium was dominant [1.02 to 8.6 cmol $(p^+)$ $kg^{-1}$] cation in all the pedons followed by magnesium [0.58 to 4.3 cmol $(p^+)$ $kg^{-1}$], sodium [0.1 to 0.66 cmol $(p^+)$ $kg^{-1}$] and potassium [0.18 to 0.6 cmol $(p^+)$ $kg^{-1}$].

The soils were low in organic carbon and available nitrogen ranged from 0.15 to 0.64 per cent and 56 to 154 kg $ha^{-1}$, respectively along different horizons and a decreasing trend was noticed with depth. Available nitrogen and organic carbon were shown to have a significant and positive association, implying that nitrogen is intimately linked to organic matter. Available phosphorus (4-10 kg $ha^{-1}$) and potassium (240-480 kg $ha^{-1}$) levels in soils ranged from low to medium and medium to high, respectively. There was a substantial positive association between accessible phosphorus and organic carbon, implying that more available P is linked to more organic matter. The DTPA-extractable Zn, Fe, Cu and Mn in mg $kg^{-1}$ varied from 0.22 to 1.80, 1.04 to 2.49, 0.23 to 3.21, 0.94 to 3.27, respectively. The content of these varied from low to high in term of availability according to the standard threshold.

The soils of the study area were classified according to Soil Taxonomy as Coarse/Fine loamy, Mixed, Hyperthermic, Calcareous, Typic Ustochrepts/ Haplustepts (Pedon 1, 2, 3 and 4) and Fine/ Coarse loamy, Mixed, Hyperthermic,Typic Ustochrepts/ Haplustepts (Pedon- 5, 6, 7, 8 and 9). The soils of pedon 1 and 3 were put under LCC class Ids due to low fertility status, drainage and less cation exchange capacity and rest of the pedons were placed in LCC class Is due to low fertility and less cation exchange capacity problems. According to Soil Irrigability classification the soilsare put under class S1s. The soils were evaluated for different crops according to soil suitability criteria and found suitable (S1) to moderately suitable (S2) for wheat, barley, horticulture, and moderately to marginally suitable for pearl millet, cotton, Pulses, Pulses, Vegetable and forestry.

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**APPENDIX-I**

**Key to macro-morphology**

| | |
|---|---|
| **Boundary** | D - Distinctness, a - abrupt, c - clear, g - gradual, d – diffuse<br>T - Topography; s - smooth, w - wavy |
| **Texture** | c - clay, cl - clay loam, l - loam, s - sand, sl - sandy loam, scl - sandy clay loam, sc -sandy clay, ls - loamy sand |
| **Structure** | Grade (G) - 0 - structureless, 1 - weak, 2 - moderate, 3 – strong<br>Size (S) - vf -very fine, f -fine, m - medium, c - coarse<br>Type (T) - cr - crumb, sg - single grain, abk - angular blocky, sbk - sub angular blocky |
| **Consistence** | Dry - s - soft, l - loose, sh - slightly hard, h - hard, vh - very hard;<br>Moist - l - loose, fr - friable, fi - firm, vfi - very firm;<br>Wet - ns - non sticky, ss - slightly sticky, s - sticky, vs - very sticky, np - non plastic, sp -slightly plastic, p - plastic, vp - very plastic |
| **Roots** | Size - vf - very fine, fn - fine, md - medium, c - coarse;<br>Quantity - vf - very few, f - few, c - common, m - many |
| **Reaction** | 0 – no effervescence, 1 - weak, 2 - moderate, 3 - strong, 4 - violent |

**APPENDIX-II**

**Land capability classification – quantification of the criteria**

| Characteristics | Class-I | Class-II | Class-III | Class-IV | Class-V | Class-VI | Class-VII | Class-VIII |
|---|---|---|---|---|---|---|---|---|
| **Topography (t)** | | | | | | | | |
| Slope (%) | 0-1 | 1-3 | 3-8 | 8-15 | upto 3 | 15-35 | 35-50 | >50 |
| Erosion | Nil | Slight | Moderate | Severe | Nil | Severe | Severe | |
| **Wetness (w)** | | | | | | | | |
| Flooding | nil (F0) | nil (F0) (F0/F1) | nil to slight (F1/F2) | slight to mod. (F3) | mod. to severe (F0/F3) | nil to severe (F0/F4) excessive | nil to very | - |
| Drainage (l) | Well | Mod. well | Imperfect | Poor | V. poor | Excessive | Excessive | Excessive |
| Permeability | Moderate | Mod. rapid | Raid slow | V. rapid, v slow | - | - | - | - |
| Infiltration rate (cm $hr^{-1}$) | 2-3.5 | 1-2.0, 3.0-5.0 | 0.5-1.0, 5.0-10.0 | <0.5, >10.0 | 2.0 | | | |
| **Physiological soil conditions** | | | | | | | | |
| Surface texture | Loam | sil & cl | sl & c | scl | s, c(m) | ls-cl | ls, s, c | ls, s, c(m) |
| Surface coarse fragments (vol %) | 1-3 | 3-15 | 15-40 | 40-75 | 15-75 | 75+ | | |
| Surface stoniness (%) | <1 | 1-3 | 3-5 | 5-8 | 8-15 | 15-40 | 40-75 | >75 |
| Subsurface coarse fragments (%) | <15 | <15 | 15-35 | 35-50 | 50-75 | 50-75 | 50-75 | >75 |
| Soil depth (cm) | >150 | 150-100 | 100-50 | 50-25 | - | 25-10 | 25-10 | <10 |
| Profile Development | Cambic/Argillic hor. A-(B)-C | A-B-C | 100-50 stratified A-C; A-B-C, | Salic(Z)/Calcic (K) hor. A-Bz-C/A-Bk-C | Az-C, A-B, C | Gypsic (y) hor. A-cy | A-C (stony) | A-C (bouldary) |
| **Fertility (f)** | | | | | | | | |
| CEC (cmol (p+) $kg^{-1}$) | 40-16 | 16-12 | 16-12 | - | - | - | - | - |
| Base saturation (%) | 80+ | 80+ | 80-50 | 50.35 | 50-35 | 35-15 | <15 | - |
| OC (0-15 cm) (%) | >10 | 0.75-1.0 | 0.5-0.75 | <0.5 | <0.5 | - | - | - |
| Salinity EC (dS $m^{-1}$) | <10 | 1-2 | 2-4 | 4-8 | 8-15 | 15-35 | 35-50 | >50 |
| Gypsum | 0.3-2.0 | 2-5 | 5-10 | 10-15 | 15-25 | >25 | - | - |

**APPENDIX-III**

**Rating based on kind and degree of limitation for surface irrigation**

| **Land characteristics** | | **Land class, degrees of limitation and rating scale** | | | | | |
|---|---|---|---|---|---|---|---|
| | **Class** | **S1 (suitable)** | | **S2** | **S3** | **N1** | **N2** |
| | **Degree of limitation** | **0** | **1** | **2** | **3** | **4** | **5** |
| | **Rating** | **90** | | **80** | **60** | **40** | **20** |
| **A. Texture** | | Clay loam | Loam; silt clay loam, silt loam | fine-loamy, fine-clayey sand clay loam, sand clay | V. fine (clayey) loamy, sand | Fine sand | Coarse sand |
| **B. Soil depth** | | | | | | | |
| Soft weathered rock | | 150+ | 100-150 | 75-100 | 50-75 | 50-20 | <20 |
| Hard rock | | 300+ | 200-300 | 100-200 | 50-100 | 50-20 | <20 |
| **C. $CaCO_3$ status (as per Sys)** | | 1-10 | 10-25 | 25-40 | 40-75 | >75 | - |
| | | 0-5 | 5-15 | 15-30 | 15-30 | 50+ | - |
| **D. Gypsum status** | | 0.5 | 0.5-2.0 | 2-5 | 5-10 | 10-25 | >25 |
| **E. Salinity and alkalinity** | | | | | | | |
| EC (dS $m^{-1}$) | | 0-4 | 4-8 | 8-16 | 8-16 | 16-30 | 30+ |
| ESP | | 0-5 | 5-15 | 15-25 | 15-25 | 25-45 | 45+ |
| **F. Drainage** | | | | | | | |
| Internal drainage (Infiltration rate, cm/hr) | | Moderate (slow)/Imperfect some what rapid 0.8-3.5 | Moderate (slow)/Imperfect some what rapid 0.8-3.5 | Slow to rapid | Very slow to very rapid | Very slow to very rapid | - |
| Natural drainage | | Well | Moderate | Imperfect | Imperfect | Poor | V. poor |
| **G. Topography** | | 0-2 | 2-5 | 5-8 | 8-15 | 15-25 | 25+ |

**APPENDIX-IV**

**Criteria/limitation ratings for evaluating soil-site suitability for Maize**

| **Soil-site characteristics** | **Degree of limitations (L) and suitability class** | | | |
|---|---|---|---|---|
| | 1 (Slight) | 2 (Moderate) | 3 (Severe) | 4 (V. Severe) |
| | **S1** | **S2** | **S3** | **N1 N2** |
| **Climatic** | | | | |
| Total rainfall (mm) | 900-1000 | 750-900 | 500-750 | <500 |
| Mean temperature in growing Season ($^0$C) | 21-32 | 33-38<br>15-20 | 39-40<br><15 | - |
| **Topographic** | | | | |
| Slope (%) | <3% | 3-5 | 5-8 | - |
| **Wetness** | | | | |
| Drainage | Well drained | Moderately<br>to imperfectly drained | Poorly/excessively drained | V. poor drained |
| **Soil** | | | | |
| | | | | |
| Texture (clay %) | l, cl, scl, sil | sl, sicl, sic, | c, ls | |
| pH (1:2.5) | 5.5-7.5 | 7.6-8.5<br>5.0-5.4 | 8.6-9.0<br><5.0 | |
| CEC | >20 | 15-20 | 10-15 | |
| OC (%) | High | Medium | Low | |
| Depth (cm) | >75 | 50 –75 | 25-50 | <25 |
| **Salinity** | | | | |
| ECe (dS $m^{-1}$) | 0-3 | 3-6 | 6-8 | >8 |
| **Sodicity (ESP) %** | Non sodic | 10-15 | >15 | |

**APPENDIX-V**

**Criteria/limitation ratings for evaluating soil-site suitability for Wheat**

| **Soil-site characteristics** | **Degree of limitations (L) and suitability class** | | | | |
|---|---|---|---|---|---|
| | 0 (None) | 1 (Slight) | 2 (Moderate) | 3 (Severe) | 4 (V. Severe) |
| | | **S1** | **S2** | **S3** | **N1 N2** |
| **Climatic** | | | | | |
| rainfall (mm) | >750 | 500-750 | 250-500 | <250 | - - |
| **Topographic (slope %)** | | | | | |
| Plain irrigated | 0-1 | 1-3 | 3-8 | >8 | >8 Others |
| Hilly unirrigated | 0-3 | 3-8 | 8-15 | 15-25 | >25 |
| Sprinkler irrigated | 0-8 | 8-15 | 15-25 | >25 | - |
| **Wetness** | | | | | |
| Flooding | Nil | Slight | Slight | Moderate | Severe |
| Drainage | Well | Mod. well | Imperfect, excessive | Poor, v. excessive | v. poor |
| **Soil** | | | | | |
| Texture (USDA) | sicl, cl, sil | sc(s), scl, l, sl+, sic(s) | sic, c, ls+ | ls(coarse) fs | s(coarse) |
| AWC (rainfed area) | >200 | 150-200 | 100-150 | 50-100 | <50 |
| Depth (cm) | >100 | 50-100 | 25-50 | <25 | - |
| $CaCO_3$ (%) | 3-10 | 0-3 | 25-50 | 50-75 | >75 |
| Gypsum (%) | 0.3-2 | <0.3; 2-5 | 5-10 | 10-25 | >25 |
| **Soil fertility** | | | | | |
| NPK rating | HHH | MMM | MLL | LLL | - |
| OM (0-20 cm) | HMM | MML | | | |
| Base saturation (%) | >80 | 50-80 | 35-50 | <35 | - |
| **Soil salinity (1m soil)** | | | | | |
| Fine, mod-fine texture | <2 mmhos | 2-4 | 4-8 | 8-15 | >15 |
| **Sodicity (ESP)** | | | | | |
| Coarse and medium texture | <8 | 8-15 | 15-25 | 25-40 | >40 |
| Fine texture | <2 | 2-4 | 4-8 | 8-15 | >15 |

**APPENDIX-VI**

**Criteria/limitation ratings for evaluating soil-site suitability for Vegetable**

| Soil-site characteristics | | | | |
|---|---|---|---|---|
| | 1 (Slight) | 2 (Moderate) | 3 (Severe) | 4 (V. Severe) |
| | S1 | S2 | S3 | N1 N2 |
| Climatic | | | | |
| Total rainfall (mm) | 600-750 | 500-600<br>750-1000 | 450-500<br>>1000 | -<br>- |
| Mean temp. grow Season ($^0$C) | 25-28 | 26-29<br>35-38 | 33-36<br>15-19 | >36 |
| Topography | | | | |
| Slope (%) | 1-3 | 3-5 | 5-10 | >8 |
| Wetness | | | | |
| Soil Drainage | Well drained | Moderately drained | Imperfectly drained | Poorly drained - |
| Soil physical properties | | | | |
| Texture (clay %) | l, cl, sl, scl | c, sl, sic, sc, c | c | ls, s |
| Depth of water (cm) | >7.5 | 50-75 | 25-30 | <25 |
| Coarse fragments vol (%) | <15 | 15-35 | >35 | |
| Salinity | | | | |
| ECe (dS $m^{-1}$) | 0-3 | 3-6 | 6-8 | >8 |
| Soil fertility | | | | |
| pH | 1-2.5 | 6.0-7.5 | 5.0-5.9<br>7.6-8.5 | <5<br>>8.5 |
| CEC | >15 | 10-15 | <10 | - |
| $CaCO_3$ (%) | Non- Calcareous | Slightly Calcareous | Strongly Calcareous | - |
| Sodicity (ESP) % | Non sodic | Slightly sodic | Strongly acidic | - |

**APPENDIX-VII**

**Criteria/limitation ratings for evaluating soil-site suitability for Oilseeds (Raya)**

| **Soil-site characteristics** | **Degree of limitations (L) and suitability class** | | | | |
|---|---|---|---|---|---|
| | 0 (None) | 1 (Slight) | 2 (Moderate) | 3 (Severe) | 4 (V. Severe) |
| | | **S1** | **S2** | **S3** | **N1 N2** |
| **Climatic** | | | | | |
| Total rainfall (mm) | >1000 | 750-1000 | 500-750 | 250-500 | <250 |
| Mean temp. grow Season ($^0$C) | | 20-26 | 27-32<br>15-19 | 33-34<br>10-14 | >35<br><10 |
| Moisture availability | | | | | |
| **Length of growing period (days)** | | >135 | 120-135 | 110-120 | <110 |
| Soil Drainage | Well | Mod. well | Imperfect | Poor | Very poorly drained |
| **Topographic** | | | | | |
| Slope (%) | 0-3 | 3-5 | 5-10 | 10-15 | >15 |
| Erosion | e0 | e0 | e1 | e2 | e3 |
| **Soil fertility** | | | | | |
| CEC (soil) cmol (p+) kg$^{-1}$ | >20 | 20-15 | 15-10 | 10-5 | <5 |
| Base saturation (%) | >80 | 50-80 | 35-50 | <35 | - |
| Organic carbon (%)<br>(0-20 cm) | >1.00 | 0.75-1.0 | 0.5-0.75 | <0.50 | - |
| **Salinity** | | | | | |
| ECe (dS m$^{-1}$) | <0.5 | 0.5-1 | 1-2 | 2-4 | >4 |
| **Soil** | | | | | |
| Texture (USDA) | sicl, cl, sil | sc(s), scl, l,<br>sl+, sic(s) | sic, c, ls+ | ls(coarse) fs | s(coarse) |
| **Sodicity** | | | | | |
| ESP | <2.5 | 2.5-5 | 5-8 | 8-15 | >15 - |
| PH (1:2.5) | 6.5-7.5 | 7.5-8.5 | 8.5-9.0 | >9.0 <6.5 | - - |

**APPENDIX-VIII**

**Criteria/limitation ratings for evaluating soil-site suitability for Vegetable**

| **Soil-site characteristics** | **Degree of limitations (L) and suitability class** | | | |
|---|---|---|---|---|
| | 1 (Slight) | 2 (Moderate) | 3 (Severe) | 4 (V. Severe) |
| | **S1** | **S2** | **S3** | **N1 N2** |
| **Climatic** | | | | |
| Total rainfall (mm) | 600 -750 | 500-600<br>750-1000 | 450-500<br>>1000 | -<br>- |
| Mean temp. in growing Season ($^{o}$C) | 25-28 | 29-32<br>20-24 | 33-36<br>15-19 | >36 |
| **Topography** | | | | |
| Slope (%) | 1-3 | 3-5 | 5-10 | >10 |
| **Wetness** | | | | |
| Drainage | Well drained | Moderately Drained | Imperfectly drained | Poorly drained |
| **Soil physical properties** | | | | |
| Texture (clay %) | sl, l, cl, scl | sicl, sic, sc, c | C | ls, s |
| Depth (cm) | >75 | 50 –75 | 25-30 | <25 |
| Coarse fragements vol (%) | <15 | 15-35 | >35 | |
| **Salinity** | | | | |
| ECe (dS $m^{-1}$) | 0-3 | 3-6 | 6-8 | >8 |
| **Soil fertility** | | | | |
| **pH** | 1-2.5 | 6.0-7.5 | 5.0-5.9<br>7.6-8.5 | <5<br>>8.5 |
| **CEC** | >15 | 10-15 | <10 | - |
| **$CaCO_3$ in root zone (%)** | Non-calcareous | Slightly Calcareous | Strongly Calcareous | - |
| **Sodicity (ESP) %** | Non sodic | Slightly sodic | Strongly sodic | - |

**APPENDIX-IX**

**Criteria/limitation ratings for evaluating soil-site suitability for Forestry**

| **Land quality** | **S1** | **S2** | **S3** | **S4** |
|---|---|---|---|---|
| **Texture** | l | c | c, s | |
| **Drainage** | Well | Mod well | Excessive | High |
| **Salinity (EC-1:2 mmhos/cm)** | <2 | 2-3 | 3-4 | >4 |
| **ESP** | <15 | 15-25 | 25-40 | >40 |
| **Risk of flooding** | Very low | Low | Medium | High |
| **Relief** | Very low | Subnormal | Excessive | Concave |
| **Slope** | Level to gently sloping | Undulating | Steep, rolling | Very steep |
| **Water holding capacity** | high | medium | Low | Very low |

**APPENDIX-X**

**Criteria/limitation ratings for evaluating soil-site suitability for Horticulture**

| **Land quality** | **S1** | **S2** | **S3** | **N** |
|---|---|---|---|---|
| **Texture** | Coarse loamy | Fine loamy | Sandy, Fine | Skeletal, Fragmental |
| **Drainage** | Well | Moderate well | Excessive | Runoff |
| **Water holding capacity** | Medium | High | Very low, low | - |
| **Fertility** | High, Medium | Low | Very low | - |
| **Slope** | Nearly level, Very gently | Gently | Moderate | Steep, very steep |
| **Erosion** | Nil to Slight | Moderate | Severe | Very Severe |

## ABSTRACT

| | | |
|---|---|---|
| **Title of thesis** | **:** | **Characterization and Classification of Soils of Experimental Area of Department of Soil Science** |
| **Full name of the degree holder** | **:** | Tamanna Saroha |
| **Admission No.** | **:** | 2019A132M |
| **Title of degree** | **:** | M.Sc. (Soil Science) |
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| **Degree awarding University/ Institute** | **:** | CCS Haryana Agricultural University, Hisar, Haryana (India) |
| **Year of award of degree** | **:** | 2021 |
| **Major subject** | **:** | Soil Science |
| **Total number of pages in thesis** | **:** | 75+vii+IX |
| **Number of words in the abstract** | **:** | 380 |

**Key words**: Pedon, land capability, irrigability and soil classification, cation exchange capacity

Nine soil profiles from Experimental Area of Department of Soil Science, CCSHAU, Hisarwere exposed and their morphological, physico-chemical characteristics were studied and classified as per Soil Taxonomy, land capability and suitability. The colour of soil of the study area was yellowish brown with dominant hue 10YR. The structure was predominantly sub-angular blocky in all pedons. The consistency of different pedons varied from slightly-sticky slightly-plastic to sticky plastic. The texture of studied pedons varied from sandy loam to sandy clayey loam with sand content being higher as compared to silt and clay in most of the pedons. Bulk density of all the pedons varied from 1.43 to 1.59 Mg $m^{-3}$ and particle density ranged from 2.81 to 2.99 Mg $m^{-3}$. The available water content varied from 9.6 to 13.8%. The pedons were observed neutral to slightly alkaline in reaction and non-saline with EC varying from 0.16 to 0.37 ds $m^{-1}$. The CEC, ESP and BSP ranged from [10.5 to 14.4 cmol ($p^+$) $kg^{-1}$], 0.95 to 4.2 % and 84.3 to 114.7 %, respectively. The exchangeable cations $Ca^{2+}$, $Mg^{2+}$, $Na^+$, and $K^+$ varied from 1.02 to 8.6, 0.58 to 4.3, 0.1 to 0.66 and 0.18 to 0.6 [cmol ($P^+$) $kg^{-1}$], with calcium and mangnesium being the dominant cations. The soils of the pedons were deficient in organic carbon and available nitrogen which decreased with depth and varied from 0.15 to 0.64 % and 56 to 134 kg $ha^{-1}$ respectively. While the soils were low to medium and medium to high in available phosphorus and potassium, respectively. The DTPA-extractable Zn, Fe, Cu and Mn in mg $kg^{-1}$ varied from 0.22 to 1.80, 1.04 to 2.49, 0.23 to 3.21, and 0.94 to 3.27, respectively. The soils of the studied area were classified according to Soil Taxonomy as Coarse/Fine loamy, Non-Calcareous/Calcareous, Mixed, Hyperthermic and Typic Ustochrepts/Haplustepts. The soils of pedons were classified as Ids (Pedon-1, 3) and Ids (Pedon-2, 4, 5, 6, 7, 8, 9), according to land capability classification. According to soil irrigability classification soils of the experimental area were classified as suitable class (S1s). The soils of the study area according to soil suitability criteria for different crops were found suitable (S1) for Wheat, barleey, oilseed and horticulture, moderately to marginally suitable (S2) for pearl millet, cotton, Pulses, Pulses, Vegetable and forestry.


**MAJOR ADVISOR** **SIGNATURE OF STUDENT**

**HEAD OF DEPARTMENT**

# CURRICULUM VITAE

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| B. Sc (Agriculture) | CCSHAU, Hisar | 2018 | 69.82% | Agriculture |
| 10+2 | Little Angels Sr. Sec. School, Sonipat | 2014 | 79.20% | English, Maths , Chemistry, Physics, Informatics Practices |
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**k) Co-curricular activities:**

- Performed as lead **Anchor** in College Youth Fest
- Grabbed an opportunity to be the **Radio Jockey** for a day
- Participated several times in soil testing awareness campaigns organized in villages
- NSS (National Service Scheme) volunteer

**l) Medals/Honours received:**

- Got awarded 1st in inter-college **Hand Ball** Competition
- Similar to Hand Ball got 1st in **Volley Ball** Competition

**[Tamanna Saroha]**

## UNDERTAKING OF THE COPYRIGHT

I, **Tamanna Saroha,** Admission No. **2019A132M,** undertake that I give copyright to the CCS HAU, Hisar of my thesis entitled **"Characterization and Classification of Soils of Experimental Area of Department of Soil Science"**

I also undertake that patent, if any, arising out of the research work conducted during the programme shall be filed by me only with due permission of the competent authority of CCS HAU, Hisar.

**(Tamanna Saroha)**