

**SPATIAL VARIABILITY OF SOIL NUTRIENTS AND CARBON
POOLS UNDER DIFFERENT LAND USES IN HILLY ZONE OF
DODA DISTRICT OF J&K**

By

MANOJ KUMAR

(J-12-D-163-A)

Thesis submitted to Faculty of Postgraduate Studies
in partial fulfillment of requirements
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**DIVISION OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu,
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2018**

Ph.D

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DIFFERENT LAND USES IN HILLY ZONE OF DODA DISTRICT OF J&K**

**MANOJ
KUMAR**

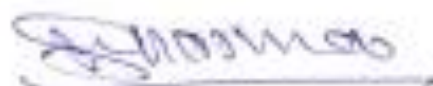
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CERTIFICATE-I

This is to certify that the thesis entitled "**Spatial variability of soil nutrients and Carbon pools under different land uses in hilly Zone of Doda district of J&K**" submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Agriculture (Soil Science and Agriculture Chemistry)** to the Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu is a record of bonafide research carried out by **Manoj Kumar**, Registration No. **J-12-D-163-A**, under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that help and assistance received during the course of thesis investigation have been fully acknowledged.

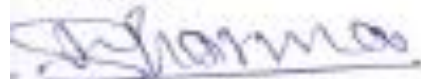
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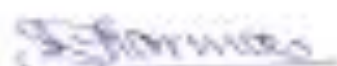
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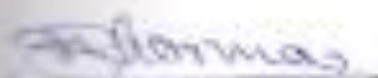
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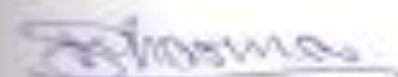


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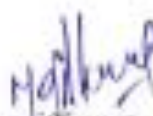
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Manoj Kumar

ABSTRACT

Title of the Thesis :	"Spatial variability of soil nutrients and carbon pools under different land uses in hilly zone of Doda district of J&K"
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Registration Number	J-12-D-163-A
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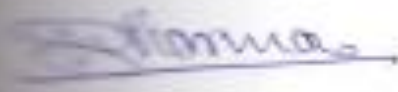
ABSTRACT

The area under study located at longitude 32°17' to 32°40'E North and latitude 34°35' to 35°10' East from mean sea level. The 236 composite soil samples from different depth viz., 0-20, 20-40, 40-60, 60-100 covering agriculture, horticulture, forest, grassland, eroded and barren land use systems by using global positioning system to assess the "spatial variability of soil nutrients, carbon pools and to establish their relationship between soil properties and nutrients /carbon pools". The mean values of pH, EC, CEC, BD, WHC, sand, silt, clay, exch. Ca, Mg, Na and CaCO₃ were 6.34, 6.28, 15.08, 8.73, 6.62, 6.36; 0.23, 0.37; 0.21, 0.19, 0.22, 0.10; 18.06, 18.95, 23.30, 21.35; 9.05, 10.90, 1.45, 1.41, 1.36, 1.49, 1.55, 1.53; 30.88, 35.61, 36.45, 36.34, 24.88, 32.83, 51.25, 40.96, 50.07, 56.64, 66.74, 64.25; 15.28, 17.83, 18.32, 17.58, 22.48, 19.99; 21.39, 25.77, 30.16, 28.57, 10.77, 14.77; 17.38, 40.63, 41.46, 39.18, 44.78, 38.65; 44.84, 49.82, 11.79, 9.87, 12.72, 8.97; 15.18, 0.93, 0.95, 1.27; 0.19, 0.87; 0.88, 1.29; 1.30, 1.07, 1.46; 1.40; 1.69 for corresponding of agriculture, horticulture, forest, grass, eroded, and barren land use systems. The pH of the soils were slightly acidic to neutral in nature and dominant textural classes were sandy loam followed by sandy clay loam in all land use systems. The mean values of available macronutrients viz NPKS in surface soils were 266.40, 276.02, 301.40, 284.78, 195.20, 216.00 ; 13.50, 13.30 ; 16.85, 14.25, 9.00, 10.60 ; 229.66, 226.80, 273.90, 270.90, 199.25, 209.95 ; 3.95, 3.71 ; 5.85 ; 4.65, 2.60, 3.25 in agriculture, horticulture forest, grass, barren and eroded land use systems respectively. The available N was medium to low, available P was high to medium and available S was medium to low in surface soil under all land use systems and decreased with increasing depth. The mean values of available micronutrient viz., iron, copper, zinc and

manganese in surface soil under agriculture, horticulture, forest, grass, eroded, and barren land use systems were 37.55, 41.71, 51.76, 47.27, 21.14, 27.36, 2.85, 3.19, 3.59, 1.28, 1.55, 2.82, 1.09, 0.92, 1.01, 0.85, 0.77, 0.87, 18.64, 20.75, 25.88, 21.68, 11.32, 1.28. The available Fe and Cu were high to medium in range and available Zn and Mn were sufficient and moderate in all land use system. The mean values of the organic carbon pools comprises of SOC, WSC, LC, MBC and TC were 6.20, 7.53, 11.75, 9.67, 4.98, 5.41, 44.12, 47.6, 59.10, 52.75, 38.40, 42.60, 2.90, 3.44, 3.69, 3.57, 1.27, 1.37, 15.36, 104.05, 117.75, 112.01, 64.25, 68.20, 25.05, 27.30, 33.56, 32.54, 20.95, 24.55 in agriculture, horticulture forest, grass, barren and eroded land use systems respectively. The soil organic pools were higher in forest land, grassland and horticulture land and agriculture land use systems and lower in eroded and barren land use systems respectively. The available macro nutrient N, P, K, S holds a positive relationship with pH, EC, CaCO_3 , silt, clay and exch. Mg at surface as well as subsurface depth. The available micronutrients including Fe, Cu, Zn and Mn were positively correlated with pH, EC, silt, clay, CEC, exchangeable Ca and Na. There was a positive co-relationship between carbon pools (SOC, WSC, LC, MBC and TC) with soil properties (pH, EC, CaCO_3).

The results indicated that available macro and micro nutrients (N, P, K, S, Fe Cu, Zn and Mn), carbon pools (SOC, WSC, LC, MBC and TC) and clay, CEC, WHC, CaCO_3 , exch. Ca, exch. Mg and Na contents were highest in forest land use system and lowest in eroded land use system followed the trend : forest land use system, grass land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system.

Key Words: Global positioning systems, land use systems, textural classes, physical, chemical properties, soil available nutrients and soil organic carbon pools.


Signature of the Advisor


Signature of the Student

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Chapter-1

Introduction

CHAPTER-1

INTRODUCTION

Characterization and comparison of spatial variation of soil nutrient are important issues in the site specific crop management, precision farming and sustainable agriculture. There is wide variation in the nutrient content of Indian soil. A management option that makes variable rate of fertilization within specific region requires better soil sampling methods and better understanding pattern and causes of variability of nutrients. Hence a comprehensive understanding of a spatial variability of soil properties is becoming increasingly essential in agriculture, soil properties vary spatially from field to a large region scale and are influenced by geology, topography, climate as well as soil and land use management strategy (Wang *et al.*, 2009). Developing accurate application maps for site specific fertilization is critical in implementing precision farming technology. Therefore, spatial variability maps showing soil properties will make it possible to reduce fertilizer use, cost and environmental pressure.

Soil quality mainly depends upon the response of soil to different land use systems and management practices, which may often modify the soil properties and productivity. Chemical properties *viz.*, soil organic carbon contents and cation-exchange-capacity have been reported to be comparatively more in soil under grass land than cultivated land system while percent base saturation is more in later land use system than in former one. Effect of land use system on soil properties provides an opportunity to evaluate sustainability of land use system thus the basic process of soil degradation in relation to land use and hence the soil and crop management must be given high research priority. The climate and soil of a region have a great bearing on sources availability and degree of decomposition of organic material in soil while the land use pattern significantly influences the soil organic carbon content.

The indiscriminate use of fertilizers over a period of time has resulted in buildup of nutrient element like phosphorus and deficiency of sulphur in many locations. Hence for sustainability of a present agriculture system and for

management of our soil resources, a spatial data base regarding the fertility status of soil is required. Application of the fertilizer by the farmers in the field without prior knowledge of soil fertility status must result in adverse effect on soils as well as crops both in turns of nutrient deficiency and toxicating either by inadequate or over use of fertilizers. With the invent of modern technologies of remote sensing GIS and GPS, it is now possible to monitor the soil fertility and crop health through systematic surveys. This will be helpful to monitor the changes in fertility status of study area with site specific nutrients requirement of the crop.

Soil properties display spatial dependence, i.e., properties at one site are statistically dependent on those at nearby sites. When an observation gives some information to the value or magnitude of its neighbour, such data are spatially dependent. Information on soil properties has often been sought for agronomic applications and was obtained from random sampling within defined areas such as plots, fields, and farms (Sauer *et al.*, 2006). However, with the help of modern equipment came the ability for strategic sampling and subsequent spatial representations of various soil properties. Spatial variation of soil properties can occur at the macro- and micro scale. Strong variations have been observed even over short distances. Geostatistical methods have been used by number of workers to describe and model spatial patterns in soil data.

Soil structure, texture, organic and inorganic binding agents determine the erodibility/stability of aggregates. Soil aggregation and soil organic carbon (SOC) are supposed to be most dynamic properties that are extremely sensitive to land use and management practices. There exists a close relationship between soil aggregation and SOC accumulation. The stable soil aggregates are the nucleus for long term stabilization of SOC. The SOC sequestration in the soil is governed by the degree of physical, chemical and physico-chemical stabilization of organic carbon inside the aggregates. For example, Soil organic carbon promotes soil aggregation, whereas aggregates in return store SOC, reducing the rate of its decomposition. The size and stability of aggregates are determined by the quantity and quality of humic compounds and by the degree of their interaction with soil particles. It can be short-term storage in macro-

aggregates (>250 μm diameter) and long-term storage in micro-aggregates (<250 μm diameter) including the widely accepted stability of C stored in the smallest size class, the silt and clay size fraction (<53 μm). The losses in SOC are concomitant with the degradation of soil structure. The studies have demonstrated that the breakdown of aggregates caused by cultivation is responsible for the loss of SOC. Therefore, aggregate fractionation of soils is another useful approach for the interpretation of SOC dynamics as affected by land use.

Soil organic carbon (SOC) preservation in different land use system is critical to maintenance of soil fertility and productivity and reduction of CO_2 losses in the atmosphere. The use of different soil management practices enhances soil carbon sequestration and its distribution in the soil profile to mitigate the green house effect. The carbon balance of terrestrial ecosystem can be changed markedly by the impact of human activities, including deforestation, biomass burning, and land-use change, which result in the release trace gases that enhance the green house effect. Soil organic carbon content exhibits considerable variability spatially, both horizontally according to land use and vertically within the soil profile. The SOC diminishes with depth regardless of vegetation, soil texture, and clay size fraction. The soils of the world are potentially viable sinks for atmospheric C. The assessment of potential C sequestration in soil requires the estimation of carbon pools under existing land uses and their spatial distribution in the soil profile.

Carbon (C) is found in all living organisms and is the major building block for life on earth. It is present in the soil organic matter, plants and animals, geologic deposits, atmosphere as carbon dioxide (CO_2) and dissolved in sea water. Concerns about increasing level of carbon dioxide in the atmosphere have a greater public awareness and scientific interest in the global carbon cycle. The soil is the largest terrestrial pool of organic carbon. Soil C dynamics is important for sustainability of production systems while at the same time contribute significantly to global C cycling (Chen *et al.*, 2004). Among other factors that affect terrestrial carbon pools are the dynamics of the soil C pool in relation to land use including natural and anthropogenic system.

Suitable land use systems can help in sequestering carbon in soil reduce the greenhouse effect. Land use change or shifts in cultivation can affect soil organic matter. Change in land use contributes C to the atmosphere in two principal ways (1) Release of C in the biomass which is either burnt or decomposed, and (2) Release of soil organic carbon (SOC) following cultivation due to enhanced mineralization brought about by change in soil moisture and temperature regimes and low rate of return of biomass to the soil. Land disturbances (such as cultivation and overgrazing) and global warming have been decreasing soil organic C stocks. Suitable land use systems can help in sequestering C in the soil and reduce the greenhouse effect.

Soil testing provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for maximizing crop yields. Precision agriculture provides an opportunity to increase production efficiency and minimize potential impacts on the environment (Ping *et al.*, 2007). Such a specific agriculture management system, however, must first address the measurement and understanding of variability. Previous studies have established that most soil properties and crop yield vary spatially (Sharma & Sharma, 2002; Sharma *et al.*, 2009), and soil variability is usually the primary factor for the variation of crop yield. Soil spatial variability is the outcome of the combined interaction of biological, chemical, and physical processes acting at multiple scales. These processes may be induced by pedological processes or management practices.

Soil is an essential part of any terrestrial ecosystem. It is defined as the product of interactions among parent materials, biota, topography and climate through time. Because of human activities, the soil is also one of the most affected parts of the ecosystem. Human activities have however resulted in soil degradation and reduction in soil functions. For sustainable crop production, reliable soil data are the most important prerequisite for the design of appropriate land use systems and soil management practices as well as for a better understanding of the environment. Though soil classification and mapping are necessary and very useful for general land use planning, what is of utmost importance to the farmer is knowing how profitable it is to grow a

particular crop or series of crops on a given plot of land and what amendments are necessary to optimize the productivity of the soil for specific crops. In the recent past, the ill effects of land use on the environment and environmental sustainability of agricultural production systems have become an issue of concern. The problems of declining soil fertility, low crop yield and accelerated soil erosion are associated with intensive and mechanized cultivation, while overexploitation of natural resources and incessant use chemical fertilizers denote intensive agriculture in the developing areas. An intimate knowledge about the types of soils and their spatial distribution is a pre-requisite in developing rational land use plan for agriculture, forestry, irrigation and drainage.

Intensively cultivated soils are being depleted with available nutrients especially secondary and micronutrients. Therefore assessment of fertility status of soils that are being intensively cultivated with high yielding crops needs to be carried out. Soil testing is usually followed by collecting composite soil samples in the fields without geographic reference. The results of such soil testing are not useful for site specific recommendations and subsequent monitoring. Soil available nutrients status of an area using Global Positioning System (GPS) will help in formulating site specific balanced fertilizer recommendation and to understand the status of soil fertility spatially and temporally. (Pulakeshi *et.al.*, 2011).

Precision agriculture, with the specific measurement of soil characteristics being an important component, provides an opportunity to increase production efficiency and minimize potential impacts on the environment. Such a specific agriculture management system, however, must first address the measurement and understanding of variability. Previous studies have established that most soil properties and crop yield vary spatially and soil variability is usually the primary factor for the variation of crop yields (Forcella, 1993; Johnson *et al.*, 2002). Soil spatial variability is the outcome of the combined interaction of biological, chemical and physical processes acting at multiple scales. These processes may be induced by pedagogical processes or management practices.

Use of GIS has emerged as a unique tool in recent years for partial analysis of natural resources and data base management. It is an effective and versatile tool to automate the transformation of soil nutrient data into soil/natural resource information system. These tools can be effectively used to prepare soil fertility maps. The GIS soil fertility maps provide clear information on the patterns and trend with respect to individual soil properties.

Soil test-based fertility management is an effective tool for increasing productivity of agricultural soils that have a high degree of spatial variability. However, major constraints impede wide scale adoption of soil testing in most developing countries. In India, these include the prevalence of small holding systems of farming as well as lack of infrastructural facilities for extensive soil testing (Sen et al., 2008). Under this context, GIS-based soil fertility mapping has appeared as a promising alternative. Use of such maps as a decision support tool for nutrient management will not only be helpful for adopting a rational approach compared to farmer practices or blanket use of state recommended fertilization, but will also reduce the necessity for elaborate plot-by-plot soil testing activities. However, information pertaining to such use of GIS-based fertility maps has been meager in India. The current study is aimed at providing a ready source of soil fertility in terms of basic properties, major nutrients, micro nutrients and carbon pools which will help in formulating site-specific balanced fertilizer recommendations, as well as understanding the spatial variability in soil properties of Doda District.

Soil organic carbon exists in two pools viz active pool and passive pool. Active pool: consists of living microbes and their products besides pool has a Short turn over time and include soil microbial biomass carbon, water soluble carbon, water soluble carbohydrates etc and it depend on agro eco system and management. Passive Pool: is comparatively more suitable than active pool and is slowly decomposable having a large turnout time. Land use has direct bearing on soil organic carbon contents. Changes in land use pattern scruall reduce sink capacity of soils. The impact of natural vegetation is sufficiently large on soil organic carbon contents indicating their sink capacity (Dinakaran and Krishnayy 2008 and Bhattacharyya *et al.*, 2008) Practices such as addition of organic

manure and residues, green manuring, inter cropping with pulses etc improve the content of soil organic carbon. Total organic carbon contents is generally low under conventional cultivators and higher under N PK + FYM amended soil. However, the information on spatial variability of nutrients and carbon pools under different land use patterns in hilly zone of Doda district of J&K is scanty. Keeping the above facts in view, the present study was undertaken with the following objectives:

- To assess the spatial variability in soil nutrients under different land uses.
- To evaluate the carbon pools in soil under different land uses.
- To establish the relationship between soil properties and nutrients/ carbon pools.

Chapter-2

Review of Literature

CHAPTER-2

REVIEW OF LITERATURE

The relevant literatures with respect to spatial variability of soil nutrients and carbon pools under different land uses have been reviewed under the following subheads.

- i. To assess the spatial variability in soil nutrients under different land uses.
- ii. To evaluate the carbon pools in soils under different land use system.
- iii. To establish relationship between soil properties and nutrients/ carbon pools.

A study was conducted by Reza *et al.* 2011 to assess the spatial variability of soil properties in Brahmaputra plains of North-Eastern India collected 1397 soil samples from a depth of 0 – 25 cm at an approximate interval of one kilometer were collected from Goalpara district of Assam showed large variability with greatest variation observed in available K (42%) where smaller variation was in pH (16%). The semi variogram from all soil properties were best fitted by exponential model and showed a highest (3.8 kilometer) range for pH and lowest (2.0 kilometer) for available nitrogen. The nugget /sill ratio indicates a strong dependence for pH (19%), moderate spatial dependence for organic carbon (60%) and a weak spatial dependence for other soil properties.

A study was conducted by Pulakeshi *et al.*, (2012) to assess available nutrient status of soils of Mantagani village in north Karnataka by GIS technique. One hundred fifteen samples (0-30cm) drawn from the farmers' fields were analysed for their fertility status and mapped by geographic information system (GIS) technique. The pH of soil samples was slightly acidic to alkaline. Soil organic matter content was low. Available nitrogen (low; 93% area), phosphorus (low 24 and Medium 76% area) was generally low to medium and available potassium and sulphur were low to high. Regarding available micronutrients, zinc and iron were deficient (88 and 72% area, respectively) whereas, copper and manganese were deficient 54 and 51% area, respectively to sufficient in these soils.

A study was undertaken by Ravikumar *et.al.*, (2007) to map major nutrients status of 48A distributary of Malaprabha Right Bank Command of Karnataka for site specific recommendations. The mapping of available nutrient status by GIS technique

indicated that majority of the area was low with respect to available nitrogen (154 to 333 kg/ha), low to medium with respect to phosphorus (5.09 to 28.60 kg/ha) and sulphur (17.30 to 53.80 kg/ha). The entire study area was observed high in potassium (375 to 887 kg/ha). Low available nitrogen status demands replenishment of soil nitrogen through organics and/or in organics to avoid soil mining for nitrogen.

A study was conducted by Mustafa (2013) to assess available nutrient status of soils of Sohag City by GIS technique. Fifty five soil samples (0-30cm) drawn during 2012 from the farmers' fields were analyzed for their fertility status and mapped by geographic information system (GIS) technique. Soil survey was carried out in Sohag area, Sohag Governorate, Egypt and the exact locations of soil samples were recorded with the help of GPS. The results indicated that all samples were moderately to strongly alkaline in soil reaction (7.4-8.8), moderately to very strongly saline (2.8-56.0 dSm⁻¹), very low to very high in organic carbon (0.02-1.6%) and calcium carbonates ranged from (0.3-32.8%). Regarding to micronutrients, the soils were sufficient in available Fe, Mn and Cu which ranged between 6.1 – 32.5, 2.4-10-7.0 and 0.24 – 6.5mg/kg respectively, whereas Zn (0.13-2.29 mg/kg) was deficient to sufficient range in soils.

Knowledge of spatial variability in soil fertility is important for site specific nutrient management. In a study conducted by Patil *et.al.*, (2011), spatial variability in properties that influence soil fertility such as soil organic carbon, available nitrogen, available P₂O₅ and available K₂O in surface soils of 154 farmers' fields of Karlawad village in Navalgund taluk of Dharwad district of Karnataka (India) were quantified and the respective thematic maps were prepared on the basis of ratings of nutrients. Soils samples (0-20 cm depth) at 154 locations in an area of 1032.15 ha were analyzed for their composition. Arc Map 9.0 with spatial analyst function of Arc GIS software was used to prepare soil fertility maps. Interpolation method employed was spline. Soils were moderately alkaline in reaction with normal Electrical Conductivity. The coefficient of variation (CV) values for soil organic carbon, available nitrogen and available P₂O₅ were 0.35, 0.32 and 0.30 respectively, in the study area and it was lower (0.16) in case of available K₂O. Organic carbon content in the soils was low in majority of the area (683 ha) while it was medium in the remaining area (350 ha). Available nitrogen content was low in 488 ha and medium in 544 ha. Available phosphorus was medium in 622 ha and low in 256 ha and high in the remaining area of

154 ha. The soils in the study area were high in available potassium status. The observed spatial variability in various soil properties that influence soil fertility will help farmers in making crop management decisions.

In a study conducted by Lopez-Granados *et.al.*, (2002) spatial patterns for seven soil chemical properties and textures were examined in two fields in southern Spain (Monclova and Caracol, province of Seville, Andalusia) in order to identify their spatial distribution for the implementation of a site-specific fertilization practice. Two sampling grids of 35x30 and 35x35 m were established in Caracol and Monclova, respectively. Fourteen and eight georeferenced soil samples per hectare were collected at two depths (0-0.1 and 0.25 – 0.35m) in early November 1998 before fertilizing and planting the winter crop. Data were analyzed both statistically and geostatistically on the basis of the semivariogram. The spatial distribution model and spatial dependence level varied both between and within locations. Some of the soil properties showed lack of spatial dependence at both depths and at the chosen interval. Such was the case for clay, organic matter and NH_4 at Monclova; and clay and NH_4 at Caracol. Bray P and exchangeable K showed a strong patchy distribution at any field and depth. It is important to know the spatial dependence of soil parameters, as management parameters with strong spatial dependence (patchy distribution) will be more readily managed and an accurate site-specific fertilization scheme for precision farming more easily developed.

In a study carried out by Sen *et.al.*, (2008), a total of 32 soil samples were collected from 0 to 15 cm depth at a 100 x 100 m grid during April 2006. GPS coordinates of the sampling points were recorded using a GARMIN Map 60 instrument. Soil physiochemical properties and available nutrient status were measured by standard procedures (Page *et al.*, 1982). Descriptive statistics of the measured soil properties showed wide variations (Except for pH, all the other parameters had Coefficient variation values greater than 24%, the highest being 90% in the case of Fe. A survey of the cropping systems and fertilization history or the study area was performed to relate nutrient variability with existing farming practices. High spatial variability in soil P content was found to be a result of differences in P application rates between vegetable farmers and rice farmers. Variability in soil S content could be related to S application by some farmers, through single superphosphate, and a lack of such application by other individuals. Potassium has

lower spatial variability compared to P and S, most likely due to generally low application rates (Wang *et al.*, 2006). Thus, the main source of variability for soil K was related to type of crop cultivated rather than application rates. The high variability for all micronutrients, except Cu, was quite surprising and needs further study for a proper explanation.

Sushil *et al.*, (2002) observed that organic carbon, clay, cation exchange capacity, water stable aggregate (WSA) and mean weight diameter (MWD) were the dominating factor influencing water retention characteristics, erosion and dispersion ratios. Forest soils had higher water retention, infiltration rate, WSA, MWD and lower dispersion and erosion ratios than the cultivated and orchards soils.

Kukul *et al.*, (2007) studied the effect of four different land uses (eroded, agricultural, forest and pasture) and reported that among the different land uses, the aggregates from the pasture land were least erodible followed by those from the forest, agricultural and eroded lands due to higher root mass density and organic matter in pasture and forest soils.

Marcos and Juan (2006) studied the effect of cultivation on the distribution of soil macro- and micro aggregates and observed that the total macro-aggregate ($>0.25 \mu\text{m}$) content was 1.7 times lower in cultivated than in undistributed soil. The cultivation mostly affects the large macro-aggregates (2800-2000 μm) and there is 92 percent decrease in this size range due to cultivation. In contrast, the micro aggregate (250-53 μm) content was two times higher in cultivated than in the undistributed soil.

Soil organic carbon (SOC) is supposed to be most dynamic property that are extremely sensitive to land use and management practices. There exists a close relationship between soil aggregation and SOC accumulation. The SOC is a vital soil attribute, enhancing soil quality and its productivity. It is related to innumerable soil functions including fertility (Reeves, 1997), soil erosion (Lal *et al.*, 1997; Lal, 2003) and soil tilth (Singh *et al.*, 1992). Soil organic matter (SOM) is closely related to SOC dynamics because it constitutes the largest terrestrial reservoir of SOC. Interaction between soil structure and SOM determines the magnitude of the SOC pool. The SOC is a dynamic factor responsible for soil structure development and is closely related to landuse (Beare *et al.*, 1994). The SOC and its fractions are basic to the aggregation process, and consequently organic matter sequestered within aggregates is protected

against degradation (Carter and Gregorich, 1996). A closer interaction between SOC and aggregation (Hermawan and Bomke, 1997) is thought to be a common feature due to the binding action of humic substances and other microbial by-products (Shepherd *et al.*, 2001). The dynamics of SOC with change in landuse and management can better be explained by the way carbon (C) is allocated in different fractions of SOM (Tan *et al.*, 2007). Several studies (Franzluebbers and Stuedemann, 2002) have suggested that certain SOC fractions like dissolved organic C (DOC), microbial biomass C (MBC), and particulate organic matter C (POM-C) are considered as more sensitive indicators of management-induced changes than the total SOC (Saviozzi *et al.*, 2001; Yang *et al.*, 2005).

Landuse cover change has emerged as a central issue within the scientific community concerned with global environment change. The emission of CO₂ to the atmosphere by landuse cover change is 124 Pg C, about half as much as released from the combustion of fossil fuels during 1850-1990 (Houghton, 1999).

Wander *et al.*, (1994) studied whether 10 yr of organic or conventional management generated difference in biologically active SOM pool. The soils receiving organic treatments accumulated biologically active C. In the cover-cropped soils, higher total C and N, particulate SOM, and reduced water dispersible organic C contents indicated that its SOM was more stable than SOM in the other organic treatments. The conventionally managed soil had the lowest biological activity. Their experiments characterized that particulate organic matter is the best index of biologically active SOM because it documented important quality (i.e. biological lability) and quantity aspects of SOM character in soils.

Potter *et al.*, (1999) observed that the amount of SOC degraded by agricultural practices and the rate of carbon sequestration in soils after restoration of grass for various periods of time. Surface (0-5 cm) SOC concentration decreased from 4.44-5.95 per cent in the prairie to 1.53-1.88 per cent in the agricultural sites. The SOC mass in the surface 120 cm of agricultural soil was 25-43 per cent lower than that of native prairie sites. The linear relationship between the lengths of time period from 6 to 60 years.

A study was conducted by Patil *et.al.* (2012) to assess available nutrient status of soils of Mantagani village in North Karnataka by GIS technique. One hundred

fifteen samples (0–30 cm) drawn from the farmers' fields were analysed for their fertility status and mapped by Geographic Information System (GIS) technique. The pH of soil samples was slightly acidic to alkaline. Soil organic matter content was low. Available nitrogen (low; 93% area), phosphorus (low; 24% area, Medium; 76% area) was generally low to medium and available potassium and sulphur were low to high. Regarding available micronutrients, zinc and iron were deficient (88% and 72% area, respectively) whereas, copper and manganese were deficient 54% and 51% area, respectively) to sufficient in these soils. Application of recommended dose of fertilizer and deficient micronutrients substantially increased the yield of crops compared to farmers' practice.

According to an analysis conducted by Jatav et.al (2007) surface soil samples were collected during November 2003 from twenty five cultivators' fields in Shimla district representing major potato growing areas of Himachal Pradesh. Data revealed wide variation in chemical properties of these soils. These were acidic to neutral in reaction and medium to high in organic carbon content. Total N, and available P and K content ranged from 0.12 to 0.34%, 13.5 to 124.0 kg ha⁻¹ and 317 to 1812 kg ha⁻¹, respectively. More than half of the samples were found to be low in available P, whereas all were high in total N and available K content. Only 16% samples were found to be deficient in DTPA-Zn. Cu content ranged from 0.52 to 3.80 ppm (mean value 1.35 ppm). Soils were rich in Fe and Mn content with an average value of 42.24 and 66.79 ppm, respectively. The correlation matrix among the chemical tests showed that organic carbon contributed most towards nutrients availability as was evident by its close association with N, K, Zn and Cu contents in these soils.

A soil survey was carried out by Pandian et.al. (2015) using global positioning system (GPS) and mapped in GIS environment and the soils were characterized. Spatial distribution of nitrogen, phosphorus, potassium, organic carbon and micro nutrients status were studied from 43 sites representing intensively direct seeding rice growing soils. . It could be understood that out of 2, 06,290 ha about 54.42% alone could be considered as normal soil, 29.28% as moderately acidic and 12.40% as moderately alkaline soil types. The soils were shallow to deep, dark yellowish brown to dark grayish brown, excessive to poorly drained, low in available nitrogen, low to medium in available phosphorus and medium to high in available potassium Micro nutrient status presented that shows that in general soil status is low in zinc, iron and

boron. There is an immediate need to alleviate the problem in related with soil such as the low organic matter content, low in zinc and Fe content of the soil and seasonal defects low rainfall, early drought and late rainfall, water logging, sodic and alkaline soil & non-availability of suitable crop varieties to meet the local situations. On the basis of the major constraints, appropriate practices were suggested to Ramnad district farmers for their sustainable management.

The study was conducted Abu Ahmed Mokammel Haque (2015) in Trishal sub-district in Bangladesh during Boro rice cultivation season 2004 to find out soil fertility status assessment and rice yield prediction by using two precision agriculture tools i.e. GIS and remote sensing. One hundred plots were selected from five land blocks (Mauza's) as well as four land types on the priority basis of Boro-Fallow-T.aman cropping pattern for soil characteristics (pH and OM) and nutrients (N, P, K, S and Zn) analysis. The status of soil pH was slightly acidic (6.0-6.5), organic matter content was low to medium (1 - 2%), soil nitrogen (N) was very low (less than 0.09%), phosphorus was very low (less than 4 ppm or $\mu\text{g/g}$ soil), potassium was low to medium (around 60 ppm or 0.152 meq/100g soil), sulfur was low to medium (around 17 ppm or $\mu\text{g/g}$ soil) and zinc content was low (less than 1 ppm or $\mu\text{g/g}$ soil). The overall actual soil nutrients status in all land blocks (Mauza's) and land types were poor in the study area. A combine nutrients status map and conceptual nutrient management zones were made for site specific nutrient management for individual crop production by GIS software. Most of the farmers in all land blocks and land types use excess amount of urea and the application rate of TSP, MP and gypsum fertilizers were not in proper dose. The total application of inorganic fertilizer was one and a half times more than the general recommendation for AEZ 9 as well as the study area. The overall average Boro rice production (3520 kg/ha) was not reached the targeted yield goal (4500 ± 500 kg/ha) of that fertilizer recommendation due to imbalanced use of the fertilizers. Soil current nutrients status basis fertilizers were recommended and area wide individual and combined fertilizer recommendation map was created by GIS software with five individual color zones; namely normal, marginal, medium, high and very high by which farmers could be easily recognized their application scale and the contribution of individual fertilizer to the total amount of fertilizer. The overall average recommended inorganic fertilizers was 301, 156, 111, 91 and only 9 kg/ha in form of urea, TSP, MP, gypsum, and zinc sulphate respectively. The total inorganic fertilizers

recommendation were gradually increased from normal zone followed by marginal, medium, high and very high zones were 359-456, 456- 552, 552-648, 648-745 and 745-841 kg/ha respectively. The total application of inorganic fertilizer during Boro rice production season of 2004 and recommended combined fertilizers were more or less similar scale but the ratio of individual fertilizer was different. The recommended combined fertilizers were calculated on the basis of higher yield goal of 6000 ± 600 kg/ha for Boro rice production.

This study was carried out by Thakor et.al. (2014) in order to map soil chemical properties and macronutrients status in North, Center and South districts zones of Gujarat state. Geographic Information System (GIS) was used in this study to present the secondary data of the soil which were obtained from Anand Agriculture University (AAU), Gujarat. The available N of soils in the north district ranged between 88 to 220 kg·ha⁻¹ with a mean value of 161 kg·ha⁻¹ while in center districts zone the available N is ranged between 63 to 251 kg·ha⁻¹ with a mean value of 143 kg·ha⁻¹ and in south districts zone available N is ranged between 94 to 251 kg·ha⁻¹ with a mean value of 163 kg·ha⁻¹ considering the soils across the North, Center and South districts zone of Gujarat have lack of available nitrogen. The available P content of soils in the north district varied from 16 to 112 kg·ha⁻¹ averaging to 50 kg·ha⁻¹ for all the soil samples tested considering the soils across the North districts zone of Gujarat have optimum availability of phosphorus content while in center districts zone the available P content of soils varied from 18 to 163 kg·ha⁻¹ averaging to 59 kg·ha⁻¹ and in south districts zone available P content of soils varied from 30 to 186 kg·ha⁻¹ averaging to 67 kg·ha⁻¹ considering the soils across the Center and South districts zone of Gujarat have high availability of phosphorus content. The available K content of soils in the north district ranged from 116 to 1081 kg·ha⁻¹ with a mean value of 331 kg·ha⁻¹ while in Center districts zone the available K content ranged from 208 to 1082 kg·ha⁻¹ with a mean value of 460 kg·ha⁻¹ and in south districts zone available K content ranged from 109 to 1022 kg·ha⁻¹ with a mean value of 488 kg·ha⁻¹ considering the soil across the North, Center and south districts zone of Gujarat have excessive amount of available potassium. The available Sulphur (S) content in the soil varied from 4 to 35 ppm with an average value of 16 ppm while in center districts zone the available S content in the soil varied from 3 to 62 ppm with an average value of 12 ppm and in south districts zone the available S content in the soil varied from 1 to 52

ppm with an average value of 14 ppm considering the soil across the North, Center and South districts zone of Gujarat have optimum amount of available sulphur.

A study was conducted to explore the spatial variability of major soil nutrients in a soybean grown region of *Malwa* plateau. From the study area, one hundred sixty two surface soil samples were collected by a random sampling strategy using GPS. Then soil physico-chemical properties i.e., pH, EC, organic carbon, soil available nutrients (N, P, K, S and Zn) were measured in laboratory. After data normalization, classical and geo-statistical analyses were used to describe soil properties and spatial correlation of soil characteristics. The mean values for pH, EC, OC content were 7.57, 0.45 dSm⁻¹ and 6.99 g kg⁻¹ with a range of 6.53-8.52, 0.08 to 1.24 dS m⁻¹ and 2.6 to 9.95 g kg⁻¹, respectively. The available N, P, and K varied from 167.98 to 393.66 kg ha⁻¹, 7.77 to 39.32 kg ha⁻¹ and 104.56 to 851.6 kg ha⁻¹ with mean value of 273.78 kg ha⁻¹, 19.38 kg ha⁻¹ and 461.35 kg ha⁻¹, respectively. The S varied from 6 to 20 mg kg⁻¹ with a mean value of 10.8 mg kg⁻¹. The available micronutrients Zn, Cu, Fe and Mn varied from 0.17 to 1.58, 0.62 to 7.8, 1.96 to 14.76 and 1.06 to 20.92 mg kg⁻¹ with mean values of 0.68, 3.01, 6.84 and 10.14 mg kg⁻¹. The coefficient of variation, which is the ratio of the standard deviation to mean expressed as a percentage is a useful measure of overall variability. The EC had the largest variation (CV = 68.89 per cent) followed by OC (CV = 23.58 per cent) while pH was found least variable (CV = 6.37 per cent). The macronutrients are i.e., NPK, the available P had the highest variability (CV=44.43 per cent) and followed by avail. K (CV=42.73 per cent) whereas N had the lowest variability (CV= 20.16). The S was found to be moderately variable (CV = 31.44 per cent). Among the micronutrients, the Cu was found to be highly variable (CV = 61.81 per cent), followed by Zn (CV=49.59 per cent) and Mn (CV= 45.49 percent) while Fe was found least variable (CV= 38.13 percent). According to the classification of Hillel (1980), pH showed low variability (<10%) and other variables except Zn showed medium variability (10% - 100%) whereas available Zn had a high variability (>100%). The range of CV for the area suggested different degrees of heterogeneity among the properties studied. All the macronutrients were found to be moderately variable with ranging from 20.26-44.43 per cent. All the micronutrients were highly variable with CV ranging from 38.13–61.81 per cent.

Studies in the tropics showed similar decline in soil organic matter following deforestation and conversion into intensive landuse such as agriculture (Van Rhoades

et al., 2000). Landuse systems affect the soil profile carbon stock. Conversion of native ecosystem to cultivated land causes rapid loss of soil C from the upper surface. The C sequestration potential of grassland and forest in a soil profile are quite apart. Forest trees favour the transfer of C into the deeper soil layers due to their deeper root systems. The overall C stock is higher in forest soils due to higher above-and below-ground biomass. However, the most of studies are concerned with mainly upper few cm of soils, although sufficient amount of C might be present in the deeper layers particularly in forest soils which are protected. Thus, a thorough understanding of the dynamics of the C stock in relation to landuse and land management strategies is of paramount importance to identify the pathways of C sequestration in soils and for maintaining SOC at a level that is essential for maintaining soil fertility and to cope up with the global warming effects.

In another study Sharma *et al.* (2008) observed that available nitrogen varied 63 – 170 kg/ha., available phosphorous from 9.4 to 84.9 kg/ha., available potassium 84 to 700 kg/ha. and available sulphur from 24.6 to 60.0 kg/ha in soils of Amritsar district of North West Punjab. Based upon the linear coefficient of correlation between micro nutrients and soil properties, a significant positive correlation found between organic carbon and N, K & S. The available nutrients showed a negative co-relation with Calcium carbonate.

An investigation conducted by Lakaria *et al.*, (2012) on soil organic carbon. pools and indices under different land use systems in vertisols of central India revealed that water soluble carbon, labile carbon, easily oxidisable carbon and soil microbial biomass carbon were the highest under forest land use system (Eucalyptus, Mahua and Tendu) and Horticulture (mango/plantation among agriculture land use systems, the continuous application of 6 ton F.Y.M / ha/annum to soyabean- wheat cropping systems significantly increased various pools of carbon under agri-horticulture system, aonla and guava plantation along with gram as rabi season companion crop improve the carbon pools over riverine land adjoining the river bed. The carbon management index (CMI) was 1.314 fold higher when only organic source of nutrients were applied. The perennial crops registered significantly higher CMI of 4.020 (mango, 3.28, eucalyptus) and 3.88 (Mahua and Tendu) fold over control under agricultural land use.

The SOC is a complex heterogeneous mixture of organic substances which imparts the physical, chemical and biological fertility of soil. Currently the scientists are gaining interest in the role of SOC as a potential sink for atmospheric. The landuse affects the distribution pattern of litter carbon to functionally different SOM pools. Light fractions (LF) generally represent only a small proportion of total SOC in biologically active soils (Gregorich *et al.*, 2006). However, changes in carbon stocks following landuse changes can be more pronounced in LF compared with bulk soil (Schwendenmann and Pendall, 2006). Actually the dynamics of SOC can be better understood by dividing it into various pools or functions that have a wide range of chemical properties and turnover times and consequently respond differently to landuse changes (Huang *et al.*, 2008).

Spatial distribution of different SOC fractions is influenced by landuse and management. Ghani *et al.*, (1996) observed the impacts of long to medium-term pastoral management practices, such as fertilization and grazing intensity, on a range of soil biological and biochemical properties viz. hot water-extractable C (HWC), water-soluble C (WSC), hot-water extractable total carbohydrates, microbial biomass-C and N and mineralisable N. Land use changes or agricultural management practices lead to changes in SOM content. However, these changes often occur gradually and therefore against the larger background suitable changes are difficult to detect in the short or medium-terms (Bolinder *et al.*, 1999; Ghani *et al.*, 1996). Fischer, (1993) showed that HWC contents in soils were strongly correlated with CO₂ evolution which would indicate that a proportion of the HWC must be easily available for microbial utilization. The hot-water extraction methods can be applied for determining the easily available pool of organic (Keeney and Bremner, 1966).

Conant *et al.*, (2004) investigated how conversion of forest and cultivated to pasture lands impacts soil C and N cycling. Their study suggested that the total soil carbon is less reliable than soil physicochemical C fractions in order to understand the mechanisms by which soil C is sequestered or lost. Total soil C did not change significantly over time following conversion from forest, though coarse (250-2000 µm) particulate organic matter C increased by a factor of 6 immediately after conversion.

Yang *et al.*, (2004) reported that the investigating the organic carbon (C) content and its chemical fractions like humic acid (HA), fulvic acid (FA), and humin

fractions in soils under forest, grass, and agricultural lands in the Mardi Watershed of Nepal observed that the higher amounts of total SOC as well as different SOC fractions, (FA, HA, humin) existed in the forest soils compared to those from grassland and agricultural soils. The carbon proportion of FA, HA, and humin fractions accounted for 25, 29, and 37 per cent of the total SOC, respectively in forest soils. The corresponding values were 34, 27, and 36 per cent in grassland, and 28, 18, and 54 per cent in agricultural land. The grassland soils showed higher FA fraction, while the agricultural soils contained lower HA fraction and higher humin fraction as compared to the forest soil. Higher HA/FA ratio and lower (HA+FA)/SOC ratio in forest soils indicates higher degree of humification and larger humification rate in this soil. Labile fractions of SOC viz dissolved organic C, hot water extractable C, microbial biomasses C (MBC) are found to be early indicators of landuse change and soil quality.

Yang *et al.*, (2004) studied the effects of land uses (forest, grassland and agricultural lands) and management practice (crop rotation, fertilization and cover crops) in a watershed on SOC fractions. Higher content of SOC existed in forest soils compared to those from grassland and agricultural areas. The rotation of grain with grass showed a significantly higher SOC compared to grain alone. The grassland soil had significantly higher FA fraction as compared to forest soils and agricultural soils, while agricultural soil contained lower HA fraction and higher humin fraction than the other two landuses. The rotation of grain + grass led to a higher C content in HA, and humin fractions and a lower C in FA fraction as compared to grain alone. The increase in HA and humin fractions caused by farmyard manure application was higher than that by chemical fertilizers. Forest soil showed higher HA/FA ratio and lower (HA+FA)/SOC ratio, which indicated that higher degree of humification and larger humification rates in forest soil were obvious as compared to other land uses.

Shrestha *et al.*, (2004) observed that the amount and distribution of SOC stock within the soil profile under dominant landuse categories (khet, bari, forest and grazing land) in a mid-hill watershed of western Nepal. In the surface soil, grazing land had the highest SOC stock, followed by *Bari*, forest and *Khet*. Whereas in depths below 20 cm, bari lands had the highest SOC stock due to translocation of C in the form of dissolved organic carbon (DOC), soil faunal activity (especially earthworms), and/or the effects of deep-rooting crops. For grazing land a marked decrease in SOC

stock by 35 per cent from the first to the second layer was observed. A significantly higher SOC stock was observed in the topsoil than in other depths within the profile of the same landuse. Bari soil contained 82 per cent and *Kheti* soil 18 per cent of the total SOC stock (1-m depth). Within the natural vegetation area, forest comprised 83 per cent of total SOC stocks and while as it was 17 per cent in grazing land. This study also indicated that the conversion of forest, grazing and *Bari* to *Khet* and the conversion of grazing land to other landuses may contribute to SOC losses from the watershed over a period of time.

Lemenih and Itanna (2004) reported soil C stock and turn over in five vegetation types and following deforestation and conversion of each vegetation types into arable lands in southern highlands of Ethiopia. The soils from farmlands had significantly lower soil C stock than under the natural vegetation. Losses of C from upper 0-10 cm soil depth following conversion of the natural vegetation to farmlands were highest in humid climate forest and lowest in semiarid climatic forest. The average rate of soil C losses ranged between 2.0 and 3.0 percent per annum in the sub-humid to humid eco-climatic zone and 0.5-1.0 per cent per annum in the semiarid lowland or the cool sub-alpine eco-climatic zones.

Zhang *et al.*, (2006) estimated landuse effects on the distribution of labile fraction organic C through soil profiles. The landuse effects on the total organic C and labile fraction organic C were mainly observed in the topsoil (0-20 cm) the upland forest, abandoned cultivated, and cultivated soils showed a considerable decrease in labile fraction organic C contents with increasing soil depth. The proportion of dissolved organic C, hot water-extractable C, and microbial biomass C to TOC increased to a maximum at a depth of about 20 to 30 cm, and then decreased with increasing soil depth in the *Deyeuxia angustifolia* wetland but not the other landuse types. This is due to leaching of the dissolved organic C from the upper soil to the lower depths.

Marcos and Juan (2006) observed that cultivation leads to decrease in different SOC fractions like particulate organic matter, carbohydrate, humic acid contents. The increase in micro-aggregates as a result of long term cultivation also causes complete loss of its particulate organic carbon content due to collapse of the macro-aggregates resulting in rapid oxidation and microbial attack. There were indications suggesting that particulate organic carbon and hot water extractable carbohydrate contents to be

valuable indicators of soil structure degradation due to exhaustive cultivation practices. Although it is well known that humic substances are chemically and structurally much more stable than non-humic substances but the results showed a surprising decrease in humic substances under continuous cultivation.

Pikul *et al.*, (2007) determined the effect of cropping rotation and soil management (including tillage, crop rotation, native grass pasture, and corn) on SOM and its components in the surface soil. The soil carbon (SC), SOM, fine particulate organic matter (fPOM), and coarse POM were measured in different sized aggregates. No tillage (NT) increased fPOM/SOM by 19 and 37 per cent compared with tillage following 4 and 10 years of NT, respectively. There was a 36 per cent increase of fPOM/SOM compared with monoculture by a 5-yr diverse rotation. Diversity of rotation or reduction of tillage increase fPOM and this may help to curb soil loss by maintaining surface conditions resistant to erosion. Yong *et al.*, (2004) reported that conversion of annually cultivated land to forage grasses has potential to increase C and N sequestration. Organic C, total N, POM-C, and POM-N content in 0-5 cm layer were significantly greater in alfalfa field than in adjacent cropland, but in the entire 0-20 cm profile, there were significant differences in SOC, POM-C and POM-N. However there was no difference in total N between alfalfa and crop soils. The POM-C and POM-N showed greater difference between the two landuse treatments than in SOC and total N.

Tan *et al.*, (2007) investigated that the distribution of light and heavy SOC fractions influenced by landuse and management systems and observed that C concentration of light fractions in all aggregate classes were significantly higher in soils under forest than under conventional tillage. This study suggested that conversion from forest to agriculture is attributed to reduction in C concentrations in both heavy and light fractions. Lower concentration of light fractions in macro-aggregates particularly in the conventional tillage than no-tillage is attributed to the destruction of larger aggregates by mechanical disruption and subsequent oxidation of protected light fractions.

The amounts of C extracted by hot-water procedure also strongly correlate with soil micro-aggregate C extracted by hot-water procedure also strongly correlate with soil micro-aggregate characteristics (Puget *et al.*, 1999). Studies by Haynes and Francis (1993) showed an increase in the amount of HWC when cultivated sites were

under pasture and a decline when soils were cultivated. Wang *et al.*, (2009) studied the influence of farming system in SOC, soil nitrogen (STN) and microbial biomass (MBC) in drought-prone environments in the semiarid loess Plateau region of northwest China. This study revealed that alfalfa-crop rotations and conventional farming increased the accumulation of soil organic matter by having high light fraction C and N contents, but this was not the case in acceleration of soil organic matter decomposition. The microbial biomass C in the continuous alfalfa and alfalfa-crop rotation systems was higher than in the conventional system. This may suggest that including alfalfa into crop rotation systems would improve soil biochemical properties and microbial activity.

The MBC/SOC ratio can be a good measure of the efficiency of organic C conversion into microbial C and the losses of soil C during decomposition, and is a soil quality parameter allowing comparisons across soils with different organic matter contents. The SOC concentration was similar between the farming systems and changed little over the years 2001 to 2004, indicating that SOC is relatively stable in a short term landuse change. The conventional farming had lowest MBC, MBN, MBC/SOC and MBN/STN ratios.

The soil is the largest active terrestrial reservoir in the global carbon cycle. The effects of landuse change on carbon storage are of increasing concern in the context of greenhouse gas emissions mitigation, and the important being those associated with the conversion of native forest into agricultural systems, especially in the tropical region. Total SOC stock under different landuse systems varies significantly. The estimates of the organic C stocks in 0-100 cm depth in the world's soils range from 1,220 Pg (1 Pg=10¹⁵ g) (Sombroek *et al.*, 1993) to about 1,550 Pg (Jobbagy and Jackson, 2000). Many studies regarding SOC are restricted to upper 10-15 cm of soil because of higher concentration of SOC in those soil layers. However, it has been shown that important amounts of stable SOC are also stored at greater depths. For understanding the SOC sequestration potential in different landuse systems we must penetrate into deeper soil layers as it is not essential that soils having higher concentration of SOC in surface soils must also have higher SOC content in the deeper soils layers or vice-versa. Some studies have revealed that SOC stock in the deeper soils showed significant variability among different landuses (Meersmans *et al.*, 2009; Debasish-Saha *et al.*, 2011).

Organic matter stored in subsoil horizons below the A Horizon has received increasing interest in recent years as high proportions of total C stored within the soil profile may be found in subsoil horizons despite of low OM concentrations (Jobbagy and Jackson, 2000). The proportion of SOM stored in the first meter of the world soils below 30 cm depth ranges between 63 and 46 per cent, except for Podzoluvisols, where 30 per cent of OC is stored below the first 30 cm (Batjes, 1996). Subsoil C may be even more important in terms of source or for CO₂ than topsoil C. Another property of subsoil C is its high radiocarbon age, which suggests that a high proportion of this C is stable at longer timescales (Paul *et al.*, 1997). Subsoil horizons with low C concentrations may not yet be saturated in organic C. It has, therefore, been suggested that these may have the potential to sequester organic carbon. In the context of climate change and SOM as potential sink for atmospheric CO₂, it is important to understand what leads to sequestration of large amounts of old C below the A horizon. Our literature is the effect of nutrient management and tillage on different SOC fractions and few are concerned with effect of landuse change on these fractions in various aggregate classes and also the depth wise distribution of these fractions down the profile.

In a study carried out by *Patil et.al.*, , spatial variability in properties that influence soil fertility such as soil organic carbon (OC), available N, available P₂O₅ and available K₂O in surface soils of 154 farmers' fields of Karlawad village in Navalgund taluk of Dharwad district of Karnataka (India) were quantified and the respective thematic maps were prepared on the basis of ratings of nutrients. Soils sampled (0-20 cm depth) at 154 locations in an area of 1032.15 ha were analyzed for their composition. Arc Map 9.0 with spatial analyst function of Arc GIS software was used to prepare soil fertility maps. Interpolation method employed was spline. Soils were moderately alkaline in reaction with normal Electrical Conductivity (EC). The coefficient of variation (CV) values for soil OC, available N and available P₂O₅ were 0.35, 0.32 and 0.30 respectively, in the study area and it was lower (0.16) in case of available K₂O. Organic carbon content in the soils was low in majority of the area (683 ha) while it was medium in the remaining area (350 ha). Available nitrogen content was low in 488 ha and medium in 544 ha. Available phosphorus was medium in 622 ha and low in 256 ha and high in the remaining area of 154 ha. The soils in the study area were high in available potassium status. The observed spatial variability in

various soil properties that influence soil fertility will help farmers in making crop management decisions.

Kriging could successfully interpolate other soil properties. Soil pH was significantly negatively correlated with organic carbon ($r = -0.434^{**}$) and available nitrogen ($r = -0.228^{**}$). A significant positive relationship observed between organic carbon and available nitrogen ($r = 0.498^{**}$) and available potassium ($r = 0.119^{**}$).

The DTPA-Zn showed negative relationship with soil pH ($r = -0.162$) and calcium carbonate ($r = -0.162^*$). An increase in pH normally affects the availability of zinc in soil adversely on. Diwale and Chavan (1999) found significant positive correlation of DTPA-Zn with organic carbon pools in soil of south Konkan. The correlation of iron with organic carbon ($r = -0.070$) was negatively non-significant and significantly correlated with pH ($r = -0.455^{**}$). Significant Spatial variability of major and micro nutrients negative relationship of available iron with pH and CaCO_3 content of soil were also reported by (Maji *et. al* 1993).

The higher addition of organic manure mostly FYM at the time of planting and the continuous mineralization of organic matter in the surface soils may be responsible for the higher values of available N (Bhat and Kuchroo 2000). Available N showed significant positive relationship with soil OC ($r = 0.846^{**}$) indicating an increase of available N to the crop with an increase in organic matter in the soil. Negative correlation was obtained between clay ($r = -0.137$) and pH ($r = -0.135$), similar relation was also reported by Sharma *et. al* (2009).

The high altitude soils under temperate climate have high P content as compared to the low altitude, warm, humid and sub-tropical climates (Singh and Datta 1987). Negative and significant correlation was also observed between soil available P and Zn ($r = -0.667^{**}$).

Negative and significant relationship between available K with that of clay content in the soil ($r = -0.485^{**}$) and CEC ($r = -0.490^{**}$), whereas a positive and significant relationship was observed between K and OC ($r = 0.298^*$). The results of the present investigation are in close consonance with the findings of Sharma *et. al* (2009).

In general, pH shows significant correlation with nutrients like macro and micronutrients (Kozak *et. al.* 2005). Perusal of the data showed significant and

positive correlation between pH and clay ($r = 0.578^{**}$) and Mg ($r = 0.452^{**}$). Negative significant correlation was found between pH and N ($r = -0.328$), P ($r = 0.274^*$), S ($r = -0.686^{**}$). Similarly, a significant and negative correlation was found between EC and N ($r = -0.356^{**}$), P ($r = -0.250^*$) and S ($r = -0.653^{**}$) while significant and positive correlation was found with Ca ($r = 0.548^{**}$) and Mg ($r = 0.436^{**}$). The OC showed positive significant correlation with N ($r = -0.255^*$) and P ($r = -0.518^{**}$) (Sharma *et al.* 2013). Negative significant correlation by CaCO_3 with N ($r = -0.374^{**}$) and S ($r = -0.637^{**}$) was also found while significant positive correlation with Ca ($r = 0.696^{**}$) and Mg ($r = -0.499^{*8}$) was found.

2.5 Relationship between soil organic carbon pools and soil properties

Soil organic carbon has a great contribution to the physical, chemical and biological properties of soil (Franchini *et al.*, 2007), it is a source of energy for the microbial biomass, participates in nutrient storage and cycling, plant available water, infiltration, aggregate formation and stability, density and soil resistance, as well as influencing cation exchange capacity (Reeves, 1997).

Soil physical properties such as clay content and mineralogy control soil C pools by influencing the susceptibility of soil C to microbial attack, but the importance of clay can vary by region (Oades, 1988). Clay particles are believed to protect some of the more easily decomposable organic compounds from rapid microbial breakdown through encrustation and entrapment (Tisdall and Oades, 1982). These two observations are largely explained by the ability of silt and clay sized particles to interact with organic matter to form micro-and macro-aggregates which protect SOC from biological mineralization. Tillage of soil leads to loss of macro-aggregates and associated SOC (Gami *et al.*, 2009).

Fine-textured soil (> 40 per cent clay) contained from 1.2 to 1.5 fold more SOC and from 2.5 to 3.5 folds more MBC than coarse-textured soil (<15 per cent clay) (Van Gestel *et al.*, 1991). Higher SOC content in fine-textured compared to coarse-textured soils may be due to differences in C input, rather than long-term decomposition dynamics, since fine-textured soils tend to be more fertile than coarse-textured soils due to likely differences in water storage capacity (Franzluebbers *et al.*, 1996).

Johnson (2002) observed that the acidic behaviour of humic substances may be, to some extent, responsible for the inverse correlation between pH and SOC content. Correlations of SOC fractions to CEC suggest that soil organic matter contributed to increase soil CEC and available K retention under Mediterranean bush in comparison with croplands (Papini *et al.*, 2011).

SOC concentrations and clay or silt+clay content is a positive linear correlations of surface soils have been found in both temperate (Konen *et al.*, 2003) and tropical environments (Zinn *et al.*, 2007). In some cases better relationships with SOC are obtained with clay (Webb *et al.*, 2003; Tan *et al.*, 2004). In others with silt plus clay (Zinn *et al.*, 2005; Shrestha *et al.*, 2007) suggested that mineralogy and possibly others factors play a role in SOC stabilization processes. Singh *et al.*, (2011) observed a significant positive correlation between SOC and clay content.

Shrestha *et al.*, (2004) studied the soil organic carbon stocks in soil aggregates under different land use systems in Nepal. They observed that the SOC content in bulk soil and aggregate size-classes were negatively correlated with bulk density. Integrated use of inorganic and organics through farmyard manure, wheat straw and green manuring of Dhaincha improved the cation exchange capacity and water holding capacity of soils with remarkable decrease in bulk density .

Zinn *et al.*, (2005) found positive linear relationships between SOC and silt+clay contents for seven soil layers to a depth of 1m in the Brazilian Cerrados indicating that textural control of SOC exists in both surface and subsurface soils. Positive relationships between SOC or total N and silt+clay content were found for both forested and cultivated soils for all of the soil depths studied. Positive relationships between soil silt+clay and both SOC and TN have also been established for each depth increment by Gami *et al.*, (2009).

Jiao *et al.*, (2009) also indicated that SOC content were positively dependent on total nitrogen content ($p < 0.05$), but negatively on bulk density or land use type ($p < 0.05$). Li *et al.*, (2007) studied to characterize changes in soil aggregation, bulk density, particle density, porosity and water holding capacity in relation to changes in total organic C and carbohydrate-C fractions under a long-term (28 years) annually-cultivated pasture (oats), and a short-term (8 years) introduced perennial pasture (cultivated once at establishment), compared with those in an adjacent native pasture.

They found significant correlations between total organic C, bulk density, particle density, porosity and water holding capacity.

Papini *et al.*, (2011) observed that the correlation coefficients of soil pH, bulk density (BD), cation exchange capacity (CEC), total N and exchangeable K were closely related to SOC content; in contrast, they showed no significant relationships to soil particle size. In particular, all SOC pools were positively related to soil total N, CEC and exchangeable K, and negatively related to soil pH and BD. The correlations in the 0.2-0.4 m layer tended to be weaker (but still significant) than in the upper layers. The significant correlation of TOC to soil total N, CEC, BD, exchangeable K and pH confirmed the multifunctional role of soil organic matter and its reliability as an indicator of soil quality. Singh *et al.*, (2011) found that the bulk density increased with soil depth and it had a negative relationship with soil organic C.

Chapter-3

Materials and Methods

CHAPTER-3

MATERIALS AND METHODS

The material used and methods employed for determinations of different parameters of the investigation have been described in this chapter under following subheads.

3.0 GENERAL INFORMATION OF THE AREA

3.1 Description of study sites.

3.2 Soils

3.3 Climate

3.4 Geology

3.5 Vegetation

3.6 Crops and cropping pattern

3.7 Collection of surface & sub surface samples

3.8 Statistical analysis

3.1 Description of study sites

Six land uses, namely agriculture, horticulture forest, grass land, eroded and barren land were selected. The selection of land uses types was done on the basis of their prevalence in the region and significance in terms of soil properties, available nutrients and organic carbon pools in hilly zone of Doda district (J&k). The study area is situated at 1700m above mean sea level located between 35° 17'-34°-11' N latitude & 75° 35'-76° 60' E longitude.

3.2 Soils

The soil are shallow, deep somewhat excessively drained mostly loamy, Skeletal and occasionally loamy and sandy loamy. These are mostly none calcareous slightly acidic to neutral in reaction, medium to high in organic carbon. The wide variation in soil characteristics are mostly associated with variation in slope, vegetation cover, parent material, slope aspect and management practices. These soils are subjected to severe erosion and have moderate to severe stoniness. These are

classified as lithic, Typic Dystricrepts and Typic Hapludols. These soils are mostly under forests and meadows but barren patches also do exist.

3.3 Climate

The climate is mostly temperate with annual rainfall of 900 mm, nearly 70 percent of it comes during winter and spring months from December to May because of dormancy in agricultural activities and not much evapotranspiration losses of rabi crops.

3.4 Geology

Geologically the area is of complex nature. The crystalline metamorphic rocks gneiss and schist occupy large area in the region. The granites are composed of quartz, feldspar, orthoclase, plagioclase, biotite, muscovite, agate.

3.5 Vegetation

A fairly good index of climate conditions and kind of soil in particular area is provided by the natural vegetation especially the type of forests, pine and deciduous forests are common. Under the conifer group, the most prevalent species are *Pinus roxburgii* (chir pine), *Pinus Wallichiana* (Blue Pine) and *Abies pindrow* (Fir). Under the broad leaf species, the common species are willows and poplars.

3.6 Crops and cropping pattern

Maize is the most dominant kharif crop, followed by rice in the irrigated areas. Summer vegetables, pulses and other crops are raised in 3% of the area in summer. Aromatic plants and medicinal plants are also grown besides temperate fruits.

3.2 COLLECTION OF SURFACE AND SUB SURFACE SAMPLES

The representative surface and depthwise soil samples were collected from different locations of temperate zone of Doda district covering the different land use system of Jammu and Kashmir.

3.2.1 Soil Physico-chemical properties

The physico-chemical properties were analyzed as per the procedures outlined below:

3.2.2. Soil pH

Soil reaction was determined in 1:2.5 soil: water suspension (w/v) with the help of glass electrode pH meter (Jackson, 1973).

3.2.3. Electrical conductivity

Electrical conductivity was estimated in 1: 2.5 soil: water ratio with EC meter as given by Jackson (1973).

3.2.4 Cation exchange capacity

Cation exchange capacity was determined by using 1N ammonium acetate method as outlined by Piper (1966).

3.2.5 Exchangeable calcium, magnesium and sodium

Exchangeable Ca and Mg were extracted by using 1N NH_4OAc and the content were determined by versenate titration method (Black, 1965).

3.2.6 Estimation of Calcium Carbonate

Calcium Carbonate was done by rapid titration method as described by Puri, 1930.

3.2.7 Bulk density

The bulk density of the soil sample was assessed by the method proposed by Chopra and Kanwar (1991).

3.2.8 Maximum water holding capacity

The WHC was estimated by Keen Roetzkowski box method (Chopra and Kanwar, 1991)

3.2.9. Particle size analysis

Mechanical analysis of soil was carried out by hydrometer method using bouyoucous hydrometer as outlined by Piper (1966).

3.3. Nutrient status of the soil samples

The nutrient status of the soil samples were analyzed as per the following method:

3.3.1. Available nitrogen

Nitrogen was determined by using alkaline permanganate as per the modified Kjeldahl method proposed by Subbiah and Asija (1956).

3.3.2. Available phosphorus

The available phosphorus was determined by the method mentioned by Olsen *et al.* (1956).

3.3.3. Available potassium

1 N NH_4OAc was used as extractant and the available potassium content was determined by feeding the extract to flame photometer (Jackson, 1973).

3.3.4. Available sulphur

The available sulphur content of soil was extracted by calcium chloride (0.15 per cent $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$). The sulphur content in the leachate was estimated by adopting barium sulphate turbidometry method using spectrophotometer at 420 nm wavelength (Black, 1965).

3.3.5 Micronutrients (Zn, Cu, Mn and Fe)

The available (DTPA-extractable) micronutrients (Zn, Cu, Mn and Fe) contents of the soil samples were determined in Atomic absorption spectrophotometer model (Hitach Z 2300) by taking 1:2 DTPA (0.005 M, pH 7.3) as suggested by Lindsay and Norvell (1978).

3.4. Soil organic carbon pools

3.4.1. Total Carbon (TC)

The Total Carbon (TC) was estimated by dry combustion method following the method of (Houba *et al.*, 1995).

3.4.2. Soil oxidizable organic carbon (SOC)

The SOC was determined as per Walkley and Black's (1934) rapid titration method (Piper 1966).

3.4.3. Microbial Carbon Biomass

Microbial Carbon Biomass in soil was determined by fumigation extraction method (Vance et al., 1987). A paired set of 20g samples of soil was taken, one part was fumigated with ethanol free chloroform in a desiccator and another was kept under identical vacuum condition without fumigation. After 24h incubation, microbial biomass carbon was extracted with 40 ml of potassium sulfate (0.5M) by shaking the sample thoroughly on a rotary shaker for 30 minutes. Eight ml of filtrate was titrated with 0.5M ferrous ammonium sulphate solution in the presence of 2 ml 0.4 N potassium dichromate and 15 ml of diacid ($H_2SO_4:H_3PO_4, 2:1$) and ferroin indicator. The MBC was calculated as follows:

$$MBC = (C_{org} \text{ in fumigated soil } - C_{org} \text{ in unfumigated soil}) / K_{ec}$$

Where $K_{ec} = 0.38$ is the factor used to convert extracted organic C to MBC.

3.4.4 Water soluble organic carbon

The water soluble carbon (HWC) was determined by method given by Schulz *et al.* (2003). Twenty gram of soil sample was weighed in 250 ml round bottomed flask and 100 ml distilled water added it. After heating to moderate boiling for one hour under reflux condenser, the samples were cooled down to room temperature immediately using a water bath and 5 drops of magnesium sulphate added to help sedimentation. After centrifuging, the supernatant solution at 3000 rpm for 10 minute, a 10 ml aliquot and 10 ml chromo sulfuric acid were heated for 20 minute in an Erlenmeyer flask in an oven at $125^{\circ}C$. The cooled mixture was titrated against 0.2 M ammonium ferrous sulphate hexahydrate standard solution using 5 drops of indicator (0.2 g N- Phenylanthranilic acid+0.2 g sodium carbonate) solution.

$$HWC \text{ (mg kg}^{-1}\text{)} = \frac{(V_a - V_b) \times 12 \times FR \times \text{Volume of aliquot (ml)} \times 1000 \times 100}{10 \times W_g \times W_{dm}}$$

Where, V_b and V_a represents volume of ammonium ferrous sulphate hexahydrate standard solution used to titrate blank and soil sample, FR is the reduction factor of the ammonium, iron, sulphate hexahydrate solution as equivalent of the reduction of $K_2Cr_2O_7$ by carbon in $mmol\text{ml}^{-1}$, W_g is the soil sample weight, W_{dm} is the dry matter of the air-dried soil sample (%).

3.4.5. Labile carbon

Labile carbon in soil sample was analyzed as per standard practical procedure outlined by Blair *et al.* (1995).

3.5. Statistical analysis

The significance of the aggregate stability is done by Completely Randomized Design (CRD), where as the significance soil organic carbon fractions and soil erodibility are done by factorial CRD. The simple coefficients of correlation were worked out between various soil properties with soil organic carbon fraction and erodibility indices. The analyses of above data have done with help of SPSS 16.0.

Table 1. Critical limits of soil characteristics

S.No.	Soil characteristic	Low status		Medium status	High status
1.	Available Nitrogen	< 280 kg ha ⁻¹		280-560 kg ha ⁻¹	> 560 kg ha ⁻¹
2.	Available Phosphorus	< 10 kg ha ⁻¹		10-25 kg ha ⁻¹	> 25 kg ha ⁻¹
3.	Available Potassium	< 110 kg ha ⁻¹		110-280 kg ha ⁻¹	> 280 kg ha ⁻¹
4.	Organic carbon	< 0.50		0.50-0.75 %	> 0.75 %
		Acidic	Normal to saline	Slightly alkaline	Alkaline
5.	pH (1:2.5)	< 6.0	6.0-8.5	8.6-9.0	> 9.0
		Normal	Critical for germination	Critical for growth of sensitive crops	Injurious to most crops
6.	EC (dS m ⁻¹)	< 1.0	1.0-2.0	2.0-4.0	> 4.0

(Murthy and Hirekerur, 1992)

S.No.	Soil characteristic	Deficit	Normal
1.	Available Sulphur	<10.00 mg kg ⁻¹	> 10.00 mg kg ⁻¹

(Tandon, 1989)

S.No.	Soil characteristic	Critical Limit
1.	Available Iron	4.5 mg kg ⁻¹
2.	Available Copper	0.2 mg Kg ⁻¹
3.	Available Zinc	0.6 mg kg ⁻¹
4.	Available Manganese	1.0 mg ka ⁻¹

(Lindsay and Norvell (1978)

Results

RESULTS

The results obtained with respect to different parameters “Spatial variability of soil nutrients and carbon pools under different land uses in hilly zone of Doda District of J&K” are presented under the following heads:

4.1 Physico-chemical properties of soils

4.2 Soil exchangeable cations

4.3 Soil available nutrients

4.4 Soil organic carbon pools

4.5 Relationship between soil properties and soil nutrients

4.6 Relationship between soil properties and SOC pools

4.1 Physico-chemical properties of soil

4.1.1 Physical properties

4.1.1.1 Bulk density

The bulk density value in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth varied from 1.37 to 1.57, 1.41 to 1.59, 1.43 to 1.61 and 1.46 to 1.69, 1.30 to 1.52, 1.35 to 1.58, 1.38 to 1.59 and 1.41 to 1.61, 1.29 to 1.44, 1.33 to 1.46, 1.37 to 1.49 and 1.39 to 1.52, 1.44 to 1.56, 1.46 to 1.60, 1.48 to 1.62 and 1.52 to 1.64, 1.48 to 1.62, 1.54 to 1.64, 1.58 to 1.67 and 1.62 to 1.68, 1.52 to 1.54, 1.55 to 1.58, 1.57 to 1.60 and 1.60 to 1.62 (g cm^{-3}) under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively (Table 2). The mean value of bulk density in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 1.45, 1.49, 1.52 and 1.56 g cm^{-3} under agriculture land use, 1.41, 1.44, 1.48 and 1.53 under horticulture land use, 1.36, 1.38, 1.42 and 1.45 g cm^{-3} under forest land use, 1.49, 1.53, 1.54 and 1.58 g cm^{-3} under grassland land use and 1.55, 1.59, 1.63 and 1.65 g cm^{-3} under eroded land use system, 1.53, 1.57, 1.59, 1.61 under barren land use system respectively. In the surface soils, the BD value found in the order of eroded land use system > barren land use system > grassland use system > agriculture land use system > horticulture land use system > forest land use system use respectively.

Table 2. Effect of different land use systems on the soil physical properties

Land uses /Depth	B.D (g/cm3)				WHC%				Sand %				Silt %				Clay%			
	min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev
Agriculture Land																				
0-20	1.37	1.57	1.45	0.11	28.16	39.13	32.83	3.35	34.16	68.34	51.25	7.98	9.42	29.46	15.28	4.72	8.28	28.28	21.39	7.35
20-40	1.41	1.59	1.49	0.06	27.15	37.21	31.14	3.46	32.51	70.54	51.53	9.28	7.21	28.45	15.93	7.07	9.28	32.32	19.61	8.02
40-60	1.43	1.61	1.52	0.05	25.16	35.72	28.94	3.58	36.12	72.44	54.28	9.38	7.42	21.23	14.25	3.77	14.12	28.10	20.78	5.31
60-100	1.46	1.69	1.56	0.06	29.13	38.66	32.10	3.36	14.28	72.45	43.37	11.97	7.45	25.24	15.90	15.06	11.11	28.30	19.33	5.98
Horticulture Land																				
0-20	1.30	1.52	1.41	0.07	30.09	41.12	35.61	3.51	48.22	70.42	62.56	6.81	11.25	27.45	17.83	4.80	20.12	32.12	25.77	3.75
20-40	1.35	1.58	1.44	0.07	29.41	38.13	33.77	2.70	56.54	70.25	61.38	3.71	11.48	27.45	17.21	5.79	19.24	35.12	26.53	4.73
40-60	1.38	1.59	1.48	0.06	28.30	35.02	31.66	2.40	54.47	70.48	63.01	5.69	11.39	29.41	16.19	51.28	19.52	33.26	26.71	4.54
60-100	1.41	1.61	1.53	0.06	26.42	33.13	29.78	2.75	51.23	70.40	62.96	5.17	7.49	27.45	17.70	5.82	24.12	36.40	27.67	4.62
Forest Land																				
0-20	1.29	1.44	1.36	0.05	34.16	38.74	36.45	1.49	24.4	61.24	50.07	10.62	11.56	39.5	18.32	8.58	19.28	36.12	30.16	5.24
20-40	1.33	1.46	1.38	0.04	32.15	36.04	34.10	1.70	25.4	58.24	47.94	8.82	15.46	39.5	23.12	7.13	20.11	37.52	28.94	6.22
40-60	1.37	1.49	1.42	0.04	30.81	36.88	32.35	1.87	23.4	61.2	50.22	10.36	11.5	39.2	20.61	7.81	15.26	37.2	29.14	6.47
60-100	1.39	1.52	1.45	0.05	28.16	35.16	31.66	1.77	23.1	65.24	52.04	11.76	9.44	39.3	18.67	9.16	13.02	37.4	29.26	6.79
Grassland																				
0-20	1.44	1.56	1.49	0.03	30.18	42.50	36.34	3.30	40.46	65.45	56.64	7.70	10.23	27.42	17.58	5.22	10.43	52.38	28.57	9.11
20-40	1.46	1.60	1.53	0.05	28.80	40.50	34.65	3.84	45.45	63.44	57.50	5.25	11.39	21.46	15.98	3.63	16.33	53.21	28.34	7.06
40-60	1.48	1.62	1.54	0.05	29.06	38.50	33.78	3.58	48.46	65.24	56.71	6.30	11.46	25.24	16.57	4.17	16.34	51.54	27.26	7.71
60-100	1.52	1.64	1.58	0.04	26.15	35.42	30.79	3.70	40.53	66.22	56.64	7.36	9.49	25.23	15.69	5.22	12.43	62.24	27.44	9.40
Eroded Land																				
0-20	1.48	1.62	1.55	0.06	23.62	30.15	24.88	3.20	64.24	69.25	66.74	3.54	19.46	25.51	22.48	4.27	10.25	11.29	10.77	0.73
20-40	1.54	1.64	1.59	0.07	22.16	29.23	23.69	3.58	61.14	66.43	63.78	3.74	21.30	21.53	21.41	0.16	12.27	17.33	14.80	3.57
40-60	1.58	1.67	1.63	0.04	21.13	28.66	22.39	3.20	58.36	60.34	59.35	1.40	23.19	23.42	23.30	0.16	16.47	18.22	17.34	1.23
60-100	1.62	1.68	1.65	0.03	20.42	24.35	21.38	1.36	57.25	61.26	59.25	2.83	25.48	29.44	27.46	2.80	13.26	13.31	13.28	0.03
Barren Land																				
0-20	1.52	1.54	1.53	0.07	28.62	33.15	30.88	3.2	61.24	67.25	64.25	3.54	16.46	23.51	19.99	4.27	12.25	15.29	14.77	0.73
20-40	1.55	1.58	1.57	0.10	26.16	31.23	28.69	3.58	58.14	64.43	61.29	3.74	18.30	19.53	18.92	0.16	14.27	18.33	18.80	3.57
40-60	1.57	1.60	1.59	0.11	25.13	29.66	27.4	3.2	55.36	58.34	56.85	1.40	20.19	21.42	20.81	0.16	18.47	21.22	20.34	1.23
60-100	1.60	1.62	1.61	0.04	24.42	26.35	25.38	1.36	54.25	59.26	56.76	2.83	22.48	27.44	24.96	2.80	15.26	11.31	16.28	0.35

4.1.1.2 Water Holding Capacity

The water holding capacity in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth ranged from 28.16 to 39.30, 27.15 to 37.21, 25.16 to 35.72 and 29.13 to 38.66, 30.18 to 42.50, 28.80 to 40.50, 29.06 to 38.50 and 26.15 to 35.42, 34.16 to 38.74, 32.15 to 36.04, 30.81 to 36.88 and 28.16 to 35.16, 30.09 to 41.12, 29.41 to 38.13, 28.30 to 35.02 and 26.42 to 33.13, 28.62 to 33.15, 26.16 to 31.23, 25.13 to 29.66 and 24.42 to 26.35,, 23.62 to 30.15, 22.16 to 29.23, 21.30 to 28.66 and 20.42 to 24.35 percent under under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean value of water holding capacity in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm were 32.83, 31.14, 28.94 and 32.10 under agriculture, 35.61, 33.77, 31.66 and 29.78 percent under horticulture, 36.45, 34.10, 32.35 and 31.66 percent in forest, 36.34, 34.65, 33.78 and 30.79 percent with grassland, 24.88, 23.69, 22.39 and 21.38 percent under eroded, and 30.88, 28.69, 27.40 and 25.38 percent under barren land use systems, respectively. In the surface soils, the water holding capacity observed in the order of forest land use system > grassland use system > horticulture land use system > agriculture land use system > barren land use system > eroded land use system, respectively.

4.1.1.3 Soil texture

The value of sand in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth ranged from 34.16 to 68.34, 32.51 to 70.54, 36.12 to 72.44 and 14.28 to 72.45, 48.22 to 70.42, 56.54 to 70.25, 54.57 to 70.48 and 51.23 to 70.40, 24.40 to 61.24, 25.40 to 58.24, 23.40 to 61.20 and 23.10 to 65.24, 40.46 to 65.45, 45.45 to 63.44, 48.46 to 65.24 and 40.53 to 66.22, 64.24 to 69.25, 61.14 to 66.43, 58.36 to 60.34 and 57.25 to 61.26, 61.24 to 67.25, 58.14 to 64.43, 55.36 to 58.34 and 54.25 to 59.26 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values for sand ranged were 51.25, 51.53, 54.28 and 43.37 under agriculture, 62.56, 61.38, 63.01 and 62.96 under horticulture, 50.07, 47.94, 50.22 and 52.04 under forest, 56.64, 57.50, 56.71 and 56.64 under grassland, 66.74, 63.78, 59.35 and 59.25 under eroded, 64.25, 61.29, 56.85 and 56.76 under barren land use system. In the surface soils, the sand in the order of eroded land use system > barren land use system > horticulture land use system > grassland land use system > agriculture land use system > forest land use system, respectively.

Table 3. Soil texture class under different land use systems

Soil depth (cm)	Landuse Systems	Texture Classes
0-20	Agriculture	Sandy Clay Loam
20-40		Sandy Clay Loam
0-20	Horticulture	Sandy Loam
20-40		Sandy Loam
0-20	Forest	Sandy Clay Loam
20-40		Sandy Clay Loam
0-20	Grass	Sandy Loam
20-40		Sandy Loam
0-20	Eroded	Sandy Loam
20-40		Sandy Loam
0-20	Barren	Sandy Loam
20-40		Sandy Loam

Similarly the value of silt fraction in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth ranged varied from 09.42 to 29.46, 7.21 to 28.45, 7.42 to 21.23 and 7.45 to 25.24, 11.25 to 27.45, 11.48 to 27.45, 11.39 to 29.41 and 7.49 to 27.45, 11.56 to 39.50, 15.46 to 39.50, 11.50 to 39.20 and 9.44 to 39.30, 10.23 to 27.42, 11.39 to 21.46, 11.46 to 25.44 and 9.49 to 25.23, 19.46 to 25.51, 21.30 to 21.53, 23.19 to 23.42 and 25.48 to 29.44, 16.46 to 23.51, 18.13 to 19.53, 20.19 to 21.42 and 22.48 to 27.44 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values for silt were 5.28, 15.93, 14.25 and 15.90 under agriculture, 17.83, 17.21, 16.19, 17.70 under horticulture, 18.32, 23.12, 20.61, 18.67 under forest, 17.58, 15.98, 16.57 and 15.69 under grassland, 22.48, 21.41, 23.30 and 27.46 under eroded, 19.99, 18.92, 20.81 and 24.96 under barren. In the surface soils, the silt in the order of eroded land use system > barren land use system > forest land use system > horticulture land use system > grassland land use system > horticulture land use system, respectively.

The value of clay content in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth ranged from 8.28 to 28.28, 29.28 to 32.32, 14.12 to 28.10 and 11.11 to 28.30, 20.12 to 32.12, 19.224 to 35.12, 19.52 to 33.26 and 24.12 to 36.40, 19.28 to 36.12 and 20.11 to 37.52, 15.26 to 37.02 and 13.02 to 37.40, 10.43 to 52.38, 16.33 to 53.21, 16.34 to 51.54 and 12.43 to 62.24, 10.25 to 11.29, 12.27 to 17.33, 16.47 to 18.22 and 13.26 to 13.31, 12.25 to 15.29, 14.27 to 18.33, 18.47 to 21.22 and 15.26 to 11.31 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values for clay content ranged from 21.39, 19.61, 20.78, 19.33 under agriculture, 25.77, 26.53, 26.71, 26.67 under horticulture, 30.16, 28.94, 29.14, 29.26 under forest, 28.57, 28.34, 27.26, 27.44 under grassland, 10.77, 14.80, 17.34, 13.28 under eroded, 14.77, 18.80, 20.34, 16.28 under barren. 17.38 and 18.73, 15.97 and 14.84, 67.07 and 65.60 per cent respectively. In the surface soils, the clay in the order of forest land use system > grassland use system > horticulture land use system > agriculture land use system > barren land use system > eroded land use system, respectively. The data indicates that the dominant soil textural class was sandy loam followed by sandy clay loam in all the land use systems except agriculture and forest, where sandy clay loam was predominant.

4.1.2 Chemical Properties

4.1.2.1 pH

A perusal of data given in table 5 regarding pH value in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth ranged from 6.17 to 6.52, 6.21 to 6.58, 6.29 to 6.67 and 6.34 to 6.72, 6.10 to 6.45, 6.02 to 6.86, 6.08 to 7.15 and 6.08 to 7.44, 5.12 to 5.48, 5.22 to 5.58, 5.32 to 5.68 and 5.52 to 5.72, 5.72 to 7.71, 5.96 to 7.79, 6.19 to 7.87 and 6.28 to 7.93, 5.70 to 7.76, 5.72 to 7.84, 5.18 to 7.89 and 5.99 to 7.94, 5.95 to 6.91, 6.11 to 7.40, 6.41 to 7.48 and 6.58 to 7.91 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values of pH in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 6.34, 6.39, 6.50 and 6.53 under agriculture, 6.28, 6.40, 6.75, 6.88 under horticulture, 5.30, 5.18, 5.50 and 5.62 under forest, 6.33, 6.68, 7.00 and 7.29, under grassland soils and 6.62, 6.72, 6.93 and 7.11 under eroded soils 6.36, 6.62, 6.78 and 7.04 under barren soils respectively. The pH values increased with increasing soil depth in all land use systems, the result with respect to pH indicates that soil varied from slightly acidic to natural in nature. In the surface soils, the soil pH in the order of eroded land use system, barren land use system > agriculture land use system > horticulture land use system > grassland land use system > forest land use system > respectively.

4.1.2.2 Electrical conductivity (EC)

The electrical conductivity (EC) value in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth ranged from 0.06 to 0.34, 0.04 to 0.16, 0.06 to 0.18 and 0.03 to 0.21 dSm^{-1} , 0.15 to 0.90, 0.11 to 0.90, 0.18 to 0.60 and 0.14 to 0.70 dSm^{-1} , 0.06 to 0.45, 0.04 to 0.38, 0.03 to 0.34 and 0.02 to 0.31, 0.09 to 0.26, 0.07 to 0.29, 0.09 to 0.30 and 0.11 to 0.27 0.07 to 0.14, 0.06 to 0.12, 0.08 to 0.10 and 0.04 to 0.06, 0.07 to 0.38, 0.06 to 0.35, 0.06 to 0.31 and 0.03 to 0.26 dSm^{-1} under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean value of this parameter in these land uses at depths 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm were 0.23, 0.09, 0.11 and 0.60 dSm^{-1} under agriculture, 0.37, 0.40, 0.28 and 0.31 dSm^{-1} under horticulture, 0.21, 0.21, 0.19 and 0.20 dSm^{-1} under forest, 0.19, 0.17, 0.18 and 0.18 dSm^{-1} under grassland, and 0.10, 0.06, 0.18 and 0.05 dSm^{-1} under eroded lands, 0.22, 0.15, 0.18 and 0.14 under barren land use system respectively. Generally surface soils had higher values of EC as compared to subsurface soils for all the land use systems. In the surface soils, the EC value found in the order of

Table 4. Effect of different land use systems on the soil chemical properties

Land uses /Depth		pH				EC(dS/m)				CEC (Cmol P ⁺ /Kg)				CaCO3%			
		min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev
Agriculture Land																	
0-20		6.17	6.52	6.34	0.24	0.06	0.34	0.23	0.08	17.4	19.8	18.6	1.69	1.22	1.37	1.29	0.10
20-40		6.21	6.58	6.39	0.18	0.04	0.16	0.09	0.03	16.3	17.7	17	0.7	1.33	1.42	1.34	0.01
40-60		6.29	6.67	6.50	0.18	0.06	0.18	0.11	0.04	15.2	16.3	15.75	0.3	1.39	1.49	1.44	0.07
60-100		6.34	6.72	6.53	0.26	0.03	0.21	0.06	0.04	13.4	15.4	14.4	1.41	1.47	1.52	1.49	0.03
Horticulture Land																	
0-20		6.10	6.45	6.28	0.17	0.15	0.90	0.37	21.00	17.8	20.1	18.95	3.46	1.24	1.36	1.3	0.08
20-40		6.02	6.86	6.40	0.31	0.11	0.90	0.40	0.23	16.6	19.2	17.9	3.31	1.27	1.39	1.33	0.06
40-60		6.08	7.15	6.75	0.33	0.18	0.60	0.28	0.14	14.3	18.4	16.35	3.66	1.31	1.46	1.44	0.05
60-100		6.12	7.44	6.88	0.38	0.14	0.70	0.31	0.16	13.4	16.3	14.85	3.47	1.35	1.59	1.62	0.09
Forest Land																	
0-20		5.12	5.48	5.30	0.25	0.06	0.42	0.21	0.10	12.30	34.30	23.30	8.65	0.61	1.52	1.07	0.23
20-40		5.22	5.58	5.18	0.06	0.04	0.38	0.21	0.11	11.40	33.50	22.45	8.61	1.09	1.68	1.37	0.19
40-60		5.32	5.68	5.50	0.25	0.03	0.34	0.19	0.10	10.90	31.80	21.35	8.46	1.15	2.23	1.64	0.35
60-100		5.52	5.72	5.62	0.14	0.02	0.31	0.20	0.08	10.10	31.30	20.70	8.46	1.66	2.42	1.79	0.3
Grassland																	
0-20		5.72	7.71	6.33	0.55	0.09	0.26	0.19	0.06	19.30	23.40	21.35	1.48	0.83	1.84	1.46	0.23
20-40		5.96	7.79	6.68	0.65	0.07	0.29	0.17	0.07	18.40	21.90	20.15	1.12	0.85	1.97	1.63	0.23
40-60		6.19	7.87	7.00	0.58	0.09	0.30	0.18	0.06	17.70	20.30	19.00	0.42	0.96	2.12	1.77	0.24
60-100		6.28	7.93	7.29	0.5	0.11	0.27	0.18	0.06	16.20	19.70	17.95	1.06	1.16	2.27	1.92	0.23
Eroded Land																	
0-20		5.7	7.76	6.62	0.74	0.07	0.14	0.10	0.04	08.40	12.70	09.05	2.81	0.84	1.32	1.04	0.18
20-40		5.72	7.84	6.72	0.78	0.06	0.12	0.06	0.03	08.80	11.50	09.65	3.01	0.92	1.46	1.22	0.18
40-60		5.81	7.89	6.93	0.78	0.08	0.08	0.18	0.13	08.90	11.30	09.60	2.76	1.12	1.72	1.4	0.2
60-100		5.99	7.94	7.11	0.71	0.04	0.06	0.05	0.01	08.50	11.20	09.35	2.81	0.54	1.85	1.5	0.37
Barren Land																	
0-20		5.95	6.91	6.36	0.31	0.07	0.38	0.22	0.21	11.9	15.7	13.5	5.3	1.44	2.08	1.69	0.20
20-40		6.11	7.40	6.62	0.41	0.06	0.35	0.15	0.04	10.5	15.7	13.1	5.24	1.68	2.13	1.86	0.15
40-60		6.41	7.48	6.78	0.36	0.06	0.31	0.18	0.17	9.7	14.9	12.3	5.26	1.72	2.21	1.96	0.16
60-100		6.58	7.91	7.04	0.39	0.03	0.26	0.14	0.16	8.9	13	10.95	5.22	1.92	2.34	2.08	0.13

horticulture land use system > agriculture land use system > barren land use system > forest land use system > grassland use system > eroded land use system, respectively.

4.1.2.3 Cation Exchange Capacity

The value of CEC in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth range from 17.40 to 19.80, 16.30 to 17.60, 15.20 to 16.30 and 13.40 to 15.40, 17.80 to 20.10, 16.60 to 19.20, 14.30 to 18.40 and 13.4 to 16.30, 12.30 to 34.30, 11.40 to 33.50, 10.90 to 31.81 and 10.10 to 31.30, 19.30 to 23.40, 18.40 to 21.90, 17.70 to 20.30 and 16.20 to 19.70, 8.40 to 12.70, 8.80 to 11.50, 08.90 to 11.30 and 8.50 to 11.20, 11.90 to 15.70, 10.50 to 15.70, 9.70 to 14.90 and 8.9 to 13.00 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 18.06, 17.00, 15.75, 14.04 under agriculture, 18.95, 17.09, 16.35, 14.85 under horticulture, 23.30, 22.45, 21.35, 20.70 under forest, 21.35, 20.15, 19.00, 17.95, under grassland, 9.05, 9.65, 9.60, 9.35 under eroded, 13.50, 13.10, 12.30, 10.95 under barren. In the surface soils, the CEC in the order of forest land use system > grassland use system > horticulture land use system > agriculture land use system > barren land use system > eroded land use system, respectively.

4.1.2.4 Calcium Carbonate

The value of Calcium Carbonate in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 1.22 to 1.37, 1.33 to 1.42, 1.39 to 1.49 and 1.47 to 1.52, 1.24 to 1.36, 1.27 to 1.39 and 1.31 to 1.46, 1.35 to 1.59, 0.83 to 1.84 and 0.61 to 1.52, 1.09 to 1.68, 1.15 to 2.23 and 1.66 to 2.42, 0.83 to 1.97, 0.96 to 2.12 and 1.16 to 2.27, 0.84 to 1.32, 0.92 to 1.46 and 1.12 to 1.72, 0.54 to 1.85, 1.44 to 2.08 and 1.68 to 2.13, 1.72 to 2.21 and 1.92 to 2.34, under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth ranged from 1.29, 1.34, 1.44, 1.49 under agriculture, 1.30, 1.33, 1.44, 1.62 under horticulture, 1.07, 1.37, 1.64, 1.79 under forest, 1.46, 1.63, 1.77, 1.92 under grassland, 1.04, 1.22, 1.40, 1.50 under eroded, 1.69, 1.86, 1.96, 2.08 under barren land use. In the surface soils, the Calcium Carbonate in the order of barren land use system > grass land use system > horticulture land use system > agriculture land use system > forest land use system > eroded land use system, respectively.

4.2 Soil exchangeable cations

4.2.1 Exchangeable Calcium

The value of calcium in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth range from 36.38 to 44.89, 34.18 to 43.14, 33.75 to 41.71 and 33.77 to 42.58, 37.18 to 45.75, 35.41 to 44.21 and 34.87 to 43.58, 35.31 to 44.08, 34.18 to 44.18 and 33.51 to 42.13, 32.91 to 41.18, 33.27 to 41.98 and 39.38 to 49.85, 39.05 to 49.19, 37.18 to 47.23 and 38.21 to 48.18, 38.13 to 39.18, 36.17 to 37.75 and 34.58 to 35.38, 35.69 to 36.78, 43.95 to 45.73 and 42.18 to 44.81, 40.13 to 42.58 and 41.21 to 41.88, under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 40.63, 38.66, 37.73, 38.17 under agriculture, 41.46, 39.8, 39.23, 39.69 under horticulture, 39.18, 37.82, 37.04, 37.62 under forest, 44.78, 43.29, 41.82, 42.43 under grassland, 38.65, 36.96, 34.98, 36.23 under eroded, 44.84, 43.49, 41.35, 41.54 under barren. In the surface soils, the Calcium in the order of barren land use system > grassland land use system > horticulture land use system > agriculture land use system > forest land use system > eroded land use system, respectively.

4.2.2 Exchangeable Magnesium

The value of magnesium in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth range from 6.18 to 13.78, 5.59 to 11.73, 4.21 to 9.58 and 5.25 to 11.76, 8.30 to 15.28, 6.81 to 37.76 and 5.38 to 12.25, 6.55 to 13.38, 8.98 to 10.75 and 7.51 to 8.41, 6.06 to 6.78, 7.21 to 7.54 and 9.18 to 16.25, 8.58 to 15.31, 8.05 to 14.62 and 8.58 to 15.08, 8.63 to 9.31, 6.81 to 8.28 and 4.18 to 6.58, 5.92 to 7.62, 11.58 to 18.78 and 10.18 to 16.58, 8.72 to 15.62 and 9.92 to 16.37 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 9.98, 8.66, 6.90, 8.51 under agriculture, 11.79, 10.29, 8.82, 9.97 under horticulture, 9.87, 7.96, 6.42 and 7.38 under forest, 12.72, 11.95, 11.34, 11.83 under grassland, 8.97, 7.55, 5.38, 6.77 under eroded, 15.18, 13.38, 12.17, 13.15 under barren land use. In the surface soils, the Magnesium in the order of barren land use system > grass land use system > horticulture land use system > agriculture land use system > forest land use system > eroded land use system, respectively.

Table 5. Effect of different land use systems on the soil exchangeable cations

land uses /depth	Exch. Ca (cmol/kg)				Exch. Mg (cmol/kg)				Exch. Na(mg/kg)			
	min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev
agriculture land												
0-20	36.38	44.89	40.63	2.86	6.18	13.78	9.98	2.08	0.52	1.17	0.93	0.19
20-40	34.18	43.14	38.66	2.82	5.59	11.73	8.66	1.75	0.48	1.13	0.88	0.18
40-60	33.75	41.71	37.73	2.71	4.21	9.58	6.9	1.79	0.41	1.08	0.83	0.19
60-100	33.77	42.58	38.17	2.59	5.25	11.76	8.51	1.8	0.36	1.06	0.77	0.18
Horticulture Land												
0-20	37.18	45.75	41.46	2.53	08.30	15.28	11.79	2.02	0.64	1.26	0.95	0.19
20-40	35.41	44.21	39.81	2.79	06.81	13.76	10.29	1.97	0.54	1.04	0.79	0.19
40-60	34.88	43.58	39.23	2.79	05.38	12.25	8.82	1.82	0.47	0.96	0.72	0.20
60-100	35.31	44.08	39.69	3.00	06.55	13.38	9.97	1.90	0.38	0.86	0.62	0.19
Forest Land												
0-20	34.18	44.18	39.18	3.27	8.98	10.75	9.87	1.25	0.72	1.81	1.27	0.79
20-40	33.51	42.13	37.82	3.05	7.51	8.41	7.96	0.64	0.66	1.58	1.12	0.75
40-60	32.91	41.18	37.04	2.96	6.06	6.78	6.42	0.51	0.44	1.38	0.91	0.73
60-100	33.27	41.98	37.62	3.02	7.21	7.54	7.38	0.23	0.38	0.94	0.66	0.67
Grassland												
0-20	39.38	49.85	44.78	2.73	9.18	16.25	12.72	1.93	0.48	1.34	0.91	0.22
20-40	39.05	49.19	43.29	2.78	8.58	15.31	11.95	1.87	0.44	1.29	0.87	0.21
40-60	37.18	47.23	41.82	2.75	8.05	14.62	11.34	1.74	0.41	1.22	0.82	0.20
60-100	38.21	48.18	42.43	2.73	8.58	15.08	11.83	1.69	0.18	1.12	0.65	0.24
Eroded Land												
0-20	38.13	39.18	38.65	0.74	08.63	09.31	8.97	0.48	0.27	1.47	0.87	0.85
20-40	36.17	37.75	36.96	1.11	06.81	08.28	7.55	1.04	0.42	1.42	0.82	0.86
40-60	34.58	35.38	34.98	0.57	04.18	06.58	5.38	1.70	0.40	1.41	0.81	0.86
60-100	35.69	36.78	36.235	0.77	05.92	07.62	6.77	1.20	0.37	1.37	0.77	0.86
Barren Land												
0-20	43.95	45.73	44.84	1.26	11.58	18.78	15.18	1.93	0.55	1.49	0.88	0.74
20-40	42.18	44.81	43.49	1.86	10.18	16.58	13.38	1.75	0.49	1.46	0.83	0.75
40-60	40.13	42.58	41.35	1.73	8.72	15.62	12.17	1.77	0.48	1.42	0.82	0.71
60-100	41.21	41.88	41.54	0.47	9.92	16.37	13.15	1.85	0.46	1.40	0.78	0.70

4.2.3 Exchangeable Sodium

The value of Sodium in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 0.52 to 1.17, 0.48 to 1.13, 0.41 to 1.08 and 0.36 to 1.06, 0.64 to 1.26, 0.54 to 1.04 and 0.47 to 0.96, 0.38 to 0.86, 0.72 to 1.81 and 0.66 to 1.58, 0.44 to 1.38, 0.38 to 0.94 and 0.48 to 1.34, 0.44 to 1.29, 0.41 to 1.22 and 0.18 to 1.12, 0.27 to 1.47, 0.42 to 1.42 and 0.40 to 1.41 0.37 to 1.37, 0.55 to 1.49 and 0.49 to 1.46 , 0.48 to 1.42 and 0.46 to 1.40, under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 0.93, 0.88, 0.83, 0.77 under agriculture, 0.95, 0.79, 0.72, 0.62 under horticulture, 1.27, 1.12, 0.91, 0.66 under forest, 0.91, 0.87, 0.82, 0.65 under grassland, 0.87, 0.82, 0.81, 0.77 under eroded 0.88, 0.83. 0.82, 0.78 under barren land use. In the surface soils, the Sodium in the order of forest land use system > horticulture use system> agriculture use system > grass land use system> barren land use system eroded use system >, respectively.

4.3 Available macronutrients

4.3.1 Available Nitrogen

The value of available Nitrogen in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 256.40 to 267.80, 250.30 to 270.30, 241.30 to 266.40 and 236.70 to 259.30 168.8 to 396.6, 157.6 to 381.2 and 139.9 to 370.4, 125.8 to 356.6, 258.20 to 344.6 and 252.80 to 334.8, 244.40 to 322.6, 243.80 to 316.80 and 220.80 to 336.60, 210.60 to 322.80, 205.60 to 304.60 and 232.80 to 294.80, 119.8 to 270.60, 112.2 to 264.4 and 98.8 to 260.20, 91.8 to 255.60, 154.80 to 278.80 and 152.60 to 271.00, 131 to 254.6 and 124.60 to 231.60 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 266.60, 260.25, 253.80, 248.00 under agriculture, 276.02, 271.02, 255.15, 241.2 under horticulture 301.40, 293.80, 283.50, 280.30 under forestland, 284.78, 271.60, 257.50, 222.62 under grassland, 195.20, 188.30, 179.50, 173.70 under eroded 216.00, 210.16, 196.48, 182.96 under barren land use. In the surface soils, the Nitrogen in the order of forest land land use system > grassland land use system > horticulture land use system > agriculture land use system > barren land land use system > eroded land use system soils, respectively.

Table 6. Effect of different land use systems on the soil available macronutrients

Land uses /Depth		N (kg/ha)				P (kg/ha)				K (kg/ha)				Avail S (mg/kg)			
		min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev
Agriculture Land																	
0-20		256.4	276.8	266.6	14.42	10.8	15.8	13.3	1.36	170	377.6	259.6	61.77	2.8	4.4	3.71	0.47
20-40		250.3	270.2	260.25	14.07	10.4	15.1	12.75	1.44	165.6	344.8	250	54.47	2.1	3.8	2.94	0.55
40-60		241.2	266.4	253.8	17.81	10	14.6	12.3	1.59	152.8	319.6	240.28	52	1.8	3.4	2.27	0.52
60-100		236.7	259.3	248	15.98	9.4	14.3	11.85	1.63	148.4	302.0	230.36	48.34	1.1	2.8	1.75	0.49
Horticulture Land																	
0-20		168.8	396.6	276.02	42.18	9.4	18.6	13.5	3.74	171.2	288.4	226.8	36.05	2.1	5.8	3.95	0.93
20-40		157.6	381.2	271.02	39.75	9.2	18.2	13.4	2.70	160.8	277.2	214.74	36.53	1.7	5.2	3.45	0.85
40-60		139.9	370.4	255.15	36.15	8.9	13.1	13.50	2.51	156.4	268.8	204.48	35.16	1.5	4.9	3.2	0.86
60-100		125.8	356.6	241.2	32.13	8.8	17.8	13.3	6.65	152.8	257.2	198.4	33.3	1.2	4.1	2.65	0.72
Forest Land																	
0-20		258.20	344.6	301.40	8.76	13.70	20.50	16.85	1.36	265.2	282.6	273.9	12.3	3.9	7.8	5.85	0.65
20-40		252.80	334.8	293.80	8.74	12.90	19.00	16.20	1.55	259.4	276.9	268.15	12.14	3.7	7.3	5.5	0.51
40-60		244.40	322.6	283.50	11.17	11.80	19.20	15.50	1.73	251.6	269.2	260.4	12.44	3.5	6.7	5.1	0.39
60-100		243.80	316.8	280.30	8.34	11.40	19.00	15.20	1.92	244.8	261.7	253.25	11.95	3.4	6.3	4.85	0.31
Grassland																	
0-20		220.8	336.6	284.78	41.54	11.4	17.1	14.25	2.74	262.9	278.9	270.9	11.31	3.2	6.1	4.65	0.56
20-40		210.6	322.8	271.6	39.86	10.6	16.3	13.45	2.7	255.6	270.4	263	10.46	2.9	3.8	3.35	0.53
40-60		205.6	304.6	257.5	37.45	09.9	15.7	12.80	2.51	250.8	261.2	256	7.35	2.7	5.6	4.15	0.51
60-100		232.8	294.8	222.62	77.07	09.5	14.4	11.95	2.39	244.3	252.3	248.3	5.65	2.2	5.4	3.8	0.64
Eroded Land																	
0-20		119.8	270.60	195.20	79.27	07.4	10.6	09.00	0.84	132.8	265.7	199.25	91.62	1.80	3.40	2.60	0.42
20-40		112.2	264.4	188.30	75.8	07.3	09.3	08.30	0.75	129.3	261.2	195.25	87.25	1.40	2.90	2.15	0.35
40-60		98.8	260.20	179.50	78.45	06.2	09.7	08.25	0.63	124.7	256.5	188.05	83.25	1.10	2.40	1.75	0.21
60-100		91.8	255.60	173.70	78.96	06.4	09.2	07.90	0.42	120	251.3	185.65	81.82	0.80	1.90	1.35	0.07
Barren Land																	
0-20		154.80	278.80	216.00	34.49	08.8	12.4	10.60	1.13	159.2	281.6	209.15	34.82	1.70	4.80	3.25	0.81
20-40		152.60	271.00	210.16	32.22	07.4	10.2	08.80	1.03	143.6	258	192.89	36.08	1.50	4.20	2.85	0.47
40-60		131	254.6	196.48	31.66	06.8	09.3	07.75	0.77	124.4	248.8	175.32	37.64	1.20	3.80	2.50	0.36
60-100		124.60	231.60	182.96	26.50	06.6	08.8	07.65	0.21	108.8	233.6	163.45	36.96	0.70	3.50	2.10	0.63

4.3.2 Available Phosphorus

The value of available Phosphorus in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 10.8 to 15.8, 10.4 to 15.1 and 10.0 to 14.6, 9.4 to 14.3, 9.4 to 18.6, 9.2 to 18.2, 8.9 to 13.1 and 8.8 to 17.8, 13.70 to 20.50 and 12.90 to 19.00, 11.80 to 19.20, 11.40 to 19.00 and 11.4 to 17.1, 10.6 to 16.3, 9.9 to 15.7 and 9.5 to 14.4, 7.4 to 10.6, 7.3 to 9.3 and 6.8 to 9.7, 6.6 to 9.2, 8.8 to 12.4 and 7.4 to 10.2, 6.2 to 9.3 and 6.5 to 8.8 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth ranged from 13.3, 12.75, 12.3, 11.85 under agriculture 13.5, 13.4, 13.5, 13.3 under horticulture, 16.85, 16.20, 15.50, 15.20 under forest, 14.25, 13.45, 12.80, 11.95 under grassland, 9.00, 8.30, 8.25, 7.90, under eroded 10.60, 8.80, 7.75, 7.65 under barren land use. In the surface soils, the Phosphorus in the order of forest land use system > grass land use system > horticulture land use system > agriculture land use system > barren land use system > eroded land use system, respectively.

4.3.3 Available Potassium

The value of available Potassium in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 170.00 to 377.6, 165.6 to 344.8, 152.8 to 319.6 and 148.4 to 302.00, 171.20 to 288.40, 160.80 to 277.20 and 156.40 to 268.80, 152.80 to 257.20, 265.2 to 282.6 and 259.4 to 276.9, 251.6 to 269.2, 44.8 to 61.7 and 262.9 to 278.9, 255.6 to 270.4, 250.8 to 261.2 and 244.3 to 252.3, 132.8 to 265.60, 129.3 to 261.2 and 124.7 to 265.5, 120.00 to 251.3, 159.2 to 281.6 and 143.6 to 258.00, 124.4 to 248.8 and 108.8 to 233.6, under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 259.6, 250.00, 240.28, 230.36 under agriculture, 226.80, 214.74, 204.48, 198.40 under horticulture, 273.9, 268.15, 260.40, 253.25 under forest, 270.9, 263.00, 256.00, 248.3 under grassland, 199.25, 195.25, 188.05, 185.65, under eroded, 209.15, 192.89, 175.32, 163.45 under barren land use. In the surface soils, the Potassium in the order of forest land land use system > grass land land use system > agriculture land use system > horticulture land use system > barren land land use system > eroded land use system soils, respectively.

4.3.4 Available Sulphur

The value of available sulphur in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 2.80 to 4.40, 2.10 to 3.80 and 1.80 to 3.40, 1.10 to 2.80, 2.10 to 5.18, 1.70 to 5.20, 1.50 to 4.90 and 1.20 to 4.10, 0.9 to 7.8 and 3.7 to 7.3, 3.5 to 6.7, 3.4 to 6.3 and 3.2 to 6.1, 2.9 to 3.8, 2.7 to 5.6 and 2.2 to 5.4 , 1.80 to 3.40, 1.40 to 2.90 and 1.10 to 2.40, 0.80 to 1.90, 1.70 to 4.80 and 1.50 to 4.20, 1.20 to 3.80 and 0.70 to 3.50 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 3.71, 2.94, 2.27, 1.75 under agriculture 3.95, 3.45, 3.20, 2.65 under horticulture, 5.85, 5.50, 5.10, 4.85 under forest, 4.65, 3.35, 4.15, 3.80 under grassland, 2.60, 2.15, 1.75, 1.35, under eroded 3.25, 2.85, 2.50, 2.10 under barren land use. In the surface soils, the Sulphur in the order of forest land land use system > grass land land use system > horticulture land use system > agriculture land use system > barren land use system > eroded land use system soils, respectively.

4.4 Available Micro Nutrients

4.4.1 Iron (mg/kg)

The value of available Iron in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 20.16 to 54.14, 19.25 to 44.67, 18.14 to 42.28 and 17.25 to 40.29, 16.24 to 67.17, 14.18 to 64.41 and 11.70 to 56.62, 9.49 to 54.55, 25.39 to 78.13 and 24.31 to 73.39, 20.14 to 67.16, 21.24 to 61.61 and 24.37 to 70.16, 22.29 to 67.11, 21.19 to 62.14 and 16.29 to 58.12, 17.13 to 25.15, 18.19 to 24.18 and 10.12 to 23.14, 8.18 to 12.16, 22.41 to 32.31 and 22.13 to 27.07, 21.91 to 31.68 and 21.40 to 31.48 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 37.15, 31.96, 30.21, 28.77 under agriculture, 41.71, 39.30, 34.16, 32.02 under horticulture, 51.76, 48.75, 43.65, 41.43 under forest, 47.27, 44.7, 41.67, 37.21 under grassland, 21.14, 21.19, 16.63, 10.17, under eroded 27.36, 24.07, 26.80, 26.46 under barren land use. In the surface soils, the Fe in the order of forest land land use system > grass land land use system > horticulture land use system > agriculture land use system > barren land land use system > eroded soils, respectively.

4.4.2 Copper (mg/kg)

The value of available Copper in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 1.93 to 3.59, 1.81 to 3.42, 1.72 to 3.22 and 1.52 to 3.20, 2.21 to 3.88, 1.90 to 3.73 and 1.74 to 3.61, 1.25 to 3.54, 2.07 to 3.61 and 2.05 to 3.57, 2.02 to 3.05, 2.01 to 3.02 and 1.96 to 3.98, 1.76 to 3.97, 1.44 to 3.74 and 1.21 to 3.66, 1.09 to 2.01, 1.07 to 1.99 and 1.04 to 1.87, 1.02 to 1.82, 1.14 to 3.92 and 1.13 to 3.81, 1.11 to 3.61 and 1.09 to 6.40 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 2.85, 2.65, 2.53, 2.42 under agriculture, 3.17, 2.91, 2.74, 2.54 under horticulture, 3.59, 3.25, 3.54, 3.52 under forest, 3.26, 3.10, 2.85, 2.71 under grassland, 1.55, 1.53, 1.46, 1.42, under eroded 2.82, 2.61, 2.47, 2.37 under barren land use. In the surface soils, the Cu in the order of forest land land use system > grass land land use system > horticulture land use system > agriculture land use system > barren land land use system > eroded soils, respectively.

4.4.3 Zinc (mg/kg)

The value of available zinc in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 0.23 to 1.47, 0.21 to 1.37, 0.17 to 1.14 and 0.13 to 1.06 0.98 to 0.86, 0.94 to 0.70 and 0.91 to 0.84, 0.71 to 0.82, 0.33 to 1.98, 0.27 to 1.81, 0.11 to 1.49 and 0.16 to 1.45, 0.35 to 1.67 and 0.24 to 1.61, 0.17 to 1.58, 0.11 to 1.45, 0.30 to 1.24, 0.29 to 1.21 and 0.20 to 1.19, 0.19 to 1.16, 0.22 to 1.38 and 0.21 to 1.31, 0.17 to 1.23 and 0.09 to 1.08 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 0.85, 0.79, 0.66, 0.60 under agriculture, 0.92, 0.82, 0.88, 0.77 under horticulture 1.09, 0.93, 0.77, 0.60 under forest 1.01, 0.93, 0.88, 0.78 under grassland, 0.77, 0.75, 0.70, 0.68, under eroded 0.80, 0.76, 0.70, 0.59 under barren land use. In the surface soils, the Zn in the order of forest land use system > grass land use system > horticulture land use system > agriculture land use system > barren land use system > eroded land use system, respectively.

Table 7. Effect of different land use systems on the soil available micro nutrients

Land uses /Depth		Fe (mg/kg)				Cu (mg/kg)				Zn(mg/kg)				Mn(mg/kg)			
		min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev
Agriculture Land																	
	0-20	20.16	54.14	37.15	10.94	1.93	3.59	2.85	0.5	0.23	1.47	0.85	0.36	10.12	27.16	18.64	4.32
	20-40	19.25	44.67	31.96	10.05	1.81	3.42	2.65	0.53	0.21	1.37	0.79	0.35	10.02	25.14	17.58	3.87
	40-60	18.14	42.28	30.21	8.44	1.72	3.22	2.53	0.49	0.17	1.14	0.66	0.30	8.14	21.13	14.64	3.45
	60-100	17.25	40.29	28.77	8.43	1.52	3.2	2.42	0.55	0.13	1.06	0.60	0.30	6.15	19.19	12.67	3.3
Horticulture Land																	
	0-20	16.24	67.17	41.71	16.06	2.21	3.88	3.17	0.49	0.98	0.86	0.92	0.2	11.32	30.18	20.75	5.59
	20-40	14.18	64.41	39.30	14.29	1.9	3.73	2.91	0.59	0.94	0.7	0.82	0.17	11.16	28.13	19.65	5.32
	40-60	11.70	56.62	34.16	11.67	1.74	3.61	2.74	0.64	0.91	0.84	0.88	0.23	08.05	26.14	17.10	5.08
	60-100	09.49	54.55	32.02	12.27	1.25	3.54	2.54	0.76	0.71	0.82	0.77	0.36	08.16	23.13	15.65	4.84
Forest Land																	
	0-20	25.39	78.13	51.76	17.37	2.07	3.61	3.59	0.74	0.33	1.98	1.09	0.43	16.19	30.17	25.88	5.75
	20-40	24.31	73.19	48.75	16.16	2.05	3.57	3.25	0.64	0.27	1.81	0.93	0.43	15.13	27.12	24.35	5.29
	40-60	20.14	67.16	43.65	15.93	2.02	3.05	3.54	0.73	0.11	1.49	0.77	0.46	13.13	25.13	21.78	4.84
	60-100	21.24	61.61	41.43	14.83	2.01	3.02	3.52	0.36	0.16	1.45	0.6	0.47	12.18	21.24	19.66	3.73
Grassland																	
	0-20	24.37	70.16	47.27	16.05	1.96	3.98	3.26	0.66	0.35	1.67	1.01	0.37	12.16	31.2	21.68	6.05
	20-40	22.29	67.11	44.7	15.4	1.76	3.97	3.1	0.74	0.24	1.61	0.93	0.4	11.17	30.16	20.67	5.93
	40-60	21.19	62.14	41.67	14.28	1.44	3.74	2.85	0.77	0.17	1.58	0.88	0.44	11.13	28.02	19.58	5.3
	60-100	16.29	58.12	37.21	14.5	1.21	3.66	2.71	0.77	0.11	1.45	0.78	0.46	10.3	25.14	17.72	4.55
Eroded Land																	
	0-20	17.13	25.15	21.14	5.67	1.09	2.01	1.55	0.65	0.30	1.24	0.77	0.66	9.02	13.62	11.32	3.25
	20-40	18.19	24.18	21.19	5.65	1.07	1.99	1.53	0.65	0.29	1.21	0.75	0.65	8.18	10.58	9.38	3.08
	40-60	10.12	23.14	16.63	9.20	1.04	1.87	1.46	0.59	0.20	1.19	0.70	0.70	8.14	12.14	10.14	2.83
	60-100	08.18	12.16	10.17	2.81	1.02	1.82	1.42	0.57	0.19	1.16	0.68	0.69	7.2	10.19	8.7	2.11
Barren Land																	
	0-20	22.41	32.31	27.36	7.00	1.14	3.92	2.82	0.83	0.22	1.38	0.80	0.38	10.33	15.28	12.81	3.50
	20-40	22.13	27.07	24.07	6.85	1.13	3.81	2.61	0.80	0.21	1.31	0.76	0.39	10.11	14.34	12.23	2.99
	40-60	21.91	31.68	26.80	6.91	1.11	3.61	2.47	0.76	0.17	1.23	0.70	0.44	09.16	13.21	11.19	2.86
	60-100	21.40	31.48	26.46	7.11	1.09	6.40	2.37	1.10	0.09	1.08	0.59	0.45	07.21	11.13	9.17	2.77

4.4.4 Manganese (mg/kg)

The value of available manganese in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 10.12 to 27.16, 10.02 to 25.14, 8.14 to 21.13 and 6.15 to 19.19, 11.32 to 30.18, 11.16 to 28.13 and 8.05 to 26.14, 8.14 to 23.13, 16.19 to 30.17 and 15.13 to 27.12, 13.13 to 25.13, 12.18 to 21.24 and 12.16 to 31.2, 11.17 to 30.16, 11.13 to 28.02 and 10.30 to 25.14, 9.02 to 13.62, 8.18 to 10.58 and 8.14 to 12.14, 7.20 to 10.19, 10.33 to 15.28 and 10.11 to 14.34, 9.16 to 13.21 and 7.21 to 11.13 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 18.64, 17.58, 14.64, 12.67 under agriculture, 20.75, 19.65, 17.10, 15.65 under horticulture, 25.88, 24.35, 27.78, 19.66 under forest, 21.68, 20.67, 19.58, 17.72 under grassland, 11.32, 9.38, 10.14, 8.70, under eroded 12.81, 12.23, 11.19, 9.17 under barren land uses. In the surface soils, the Manganese in the order of forest land land use system > grass land land use system > horticulture land use system > agriculture land use system > barren land land use system > eroded soils, respectively.

4.5 Soil Organic Carbon Pools

4.5.1 Soil Organic Carbon (gm/kg)

The value of Soil organic carbon in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth ranged from 3.14 to 7.98, 3.02 to 7.54, 2.15 to 7.92 and 1.39 to 6.82, 4.13 to 9.92, 3.96 to 9.29 and 3.13 to 8.89, 2.46 to 7.99, 10.35 to 13.15 and 9.84 to 12.91, 9.16 to 12.61, 9.01 to 11.98 and 7.90 to 11.44, 8.49 to 10.04, 6.09 to 11.02 and 5.19 to 10.84, 3.66 to 6.14, 3.16 to 5.80 and 2.13 to 5.18, 1.16 to 5.04, 5.76 to 5.06 and 5.13 to 4.92, 4.79 to 4.81 and 4.12 to 4.76 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 6.20, 5.58, 4.93, 4.28 under agriculture, 7.53, 7.13, 6.51, 5.73 under horticulture, 11.75, 11.38, 10.89, 10.50 under forest, 9.67, 9.27, 8.56, 8.02 under grassland, 4.90, 4.48, 3.66, 3.10, under eroded 5.41, 5.03, 4.80, 4.44 under barren land uses. In the surface soils, the soil organic carbon in the order of forest land land use system > grass land land use system > horticulture land use system > agriculture land use system > barren land land use system > eroded soils, respectively.

4.5.2 Water Soluble Carbon (mg/kg)

The value of Water Soluble Carbon in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 14.10 to 74.13, 12.12 to 64.40, 11.12 to 60.21 and 9.11 to 54.48, 15.40 to 79.80, 12.20 to 72.20 and 9.20 to 68.60, 8.50 to 64.20, 58.80 to 59.40 and 44.40 to 55.10, 40.40 to 46.70, 35.50 to 41.30 and 16.40 to 89.10, 15.80 to 79.70, 14.80 to 69.50 and 13.20 to 59.60, 29.40 to 47.40, 26.90 to 45.30 and 23.40 to 40.80, 18.60 to 34.10, 37.40 to 47.80 and 34.40 to 45.40, 27.50 to 43.60 and 24.30 to 42.50, under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 44.12, 38.26, 35.67, 31.80 under agriculture, 47.60, 42.20, 39.90, 36.35 under horticulture, 59.10, 49.75, 43.55, 38.40 under forest, 52.75, 47.75, 42.15, 36.40 under grassland, 38.40, 36.10, 32.10, 26.35 under eroded 42.60, 39.90, 35.55, 33.40 under barren land uses. In the surface soils, the Water Soluble Carbon in the order of forest land land use system > grass land land use system > horticulture land use system > agriculture land use system > barren land land use system > eroded soils, respectively.

4.5.3 Labile Carbon (gm/kg)

The value of Labile Carbon in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth ranged from 2.12 to 3.24, 1.72 to 3.42, 0.98 to 3.11 and 0.36 to 2.78, 0.36 to 6.48, 0.26 to 5.16 and 0.14 to 4.16, 0.11 to 3.18, 2.91 to 2.46 and 2.82 to 4.39, 2.66 to 4.17, 2.41 to 3.86 and 2.94 to 4.19, 2.92 to 4.04, 2.48 to 4.01 and 2.16 to 3.97, 1.16 to 1.38, 1.08 to 1.34 and 1.01 to 1.29, 0.82 to 1.21, 1.26 to 1.47 and 1.17 to 1.35, 1.04 to 1.33 and 0.93 to 1.27 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 2.90, 2.58, 2.14, 1.47 under agriculture, 3.44, 2.71, 2.05, 1.19 under horticulture, 3.69, 3.61, 3.42, 3.14 under forest, 3.57, 3.48, 3.25, 3.07 under grassland, 1.27, 1.21, 1.15, 1.02, under eroded 1.37, 1.26, 1.18, 1.10 under barren land uses. In the surface soils, the Labile Carbon in the order of forest land land use system > grass land land use system > horticulture land use system > agriculture land use system > barren land land use system > eroded soils, respectively.

Table 8. Effect of different land use systems on the Soil Organic Carbon Pools

Land uses /Depth		SOC (g/kg)				WSC (mg/kg)				LC (g/kg)				MBC (mg/kg)				TC (g/kg)			
		min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev	min	max	mean	stdev
Agriculture Land																					
0-20		3.14	7.98	6.20	1.32	14.1	74.13	44.12	19.52	2.12	3.82	2.90	0.54	70.40	90.00	83.86	6.66	20.60	29.50	25.05	6.65
20-40		3.02	7.54	5.58	1.40	12.12	64.4	38.26	18.2	1.72	3.42	2.58	0.52	56.80	78.60	67.74	6.94	19.30	26.40	22.85	5.15
40-60		2.15	6.92	4.93	1.61	11.12	60.21	35.67	16.42	0.98	3.11	2.14	0.71	45.90	70.10	58.90	8.25	21.90	31.30	26.60	5.98
60-100		1.39	6.82	4.28	1.74	9.11	54.48	31.8	15.58	0.36	2.78	1.47	0.84	37.90	61.90	51.51	8.76	17.30	25.20	21.25	5.34
Horticulture Land																					
0-20		4.13	9.92	7.53	1.25	15.4	79.8	47.6	18.29	0.36	6.48	3.44	1.86	70.6	135.5	104.05	17.63	11.4	43.2	27.3	10.94
20-40		3.96	9.29	7.13	1.21	12.2	72.2	42.2	18.55	0.26	5.16	2.71	1.46	61.4	126	94.7	18.24	9.2	42.4	25.8	11.19
40-60		3.13	8.89	6.51	1.4	9.2	68.6	38.9	18.77	0.14	4.16	2.05	1.03	56.4	108	83.2	13.88	9.0	41.9	25.45	10.86
60-100		2.46	7.99	5.73	1.33	8.5	64.2	36.35	17.59	0.11	3.18	1.19	0.7	47.5	92	70.75	11.89	8.9	39.8	24.35	10.56
Forest Land																					
0-20		10.35	13.15	11.75	0.92	58.80	59.40	59.10	2.55	2.91	4.46	3.69	0.48	92.40	141.10	117.75	10.17	21.20	44.40	33.56	9.49
20-40		09.84	12.91	11.38	0.98	44.40	55.10	49.75	9.69	2.82	4.39	3.61	0.47	82.30	136.60	110.45	11.56	18.30	42.30	30.07	8.93
40-60		09.16	12.61	10.89	1.07	40.40	46.70	43.55	6.58	2.66	4.17	3.42	0.51	72.40	128.20	101.30	12.75	16.60	37.30	28.00	8.58
60-100		09.01	11.98	10.50	1.07	35.50	41.30	38.40	6.22	2.41	3.86	3.14	0.48	60.20	125.30	93.75	15.54	14.90	37.50	25.73	8.23
Grassland																					
0-20		7.90	11.44	9.67	0.95	16.4	89.1	52.75	24.28	2.94	4.19	3.57	0.41	75.6	138.1	112.01	18.53	16.80	48.30	32.54	8.23
20-40		8.49	10.04	9.27	0.86	15.8	79.7	47.75	21.89	2.92	4.04	3.48	0.39	52.9	121.3	91.62	18.8	14.20	36.30	29.33	6.80
40-60		6.09	11.02	8.56	1.48	14.8	69.5	42.15	19.05	2.48	4.01	3.25	0.47	36.6	88.6	68.71	16.27	12.60	34.10	27.07	7.09
60-100		5.19	10.84	8.02	1.30	13.2	59.6	36.4	15.34	2.16	3.97	3.07	0.52	24.4	67.7	49.3	11.04	11.70	32.70	24.65	7.44
Eroded Land																					
0-20		3.66	6.14	4.90	1.75	29.4	47.4	38.4	4.34	1.16	1.38	1.27	0.16	56.20	70.30	64.25	9.97	16.60	25.30	20.95	6.37
20-40		3.16	5.80	4.48	1.99	26.9	45.3	36.1	4.14	1.08	1.34	1.21	0.18	54.40	58.80	57.60	2.40	15.40	23.40	19.40	5.27
40-60		2.13	5.18	3.66	2.15	23.4	40.8	32.1	4.03	1.01	1.29	1.15	0.20	48.90	50.30	50.60	0.99	19.20	29.30	24.25	5.37
60-100		1.16	5.04	3.10	2.74	18.6	34.1	26.35	3.56	0.82	1.21	1.02	0.28	33.40	4.80	20.10	7.35	11.60	22.40	17.00	5.89
Barren Land																					
0-20		5.76	5.06	5.41	0.21	37.40	47.80	42.60	10.89	1.26	1.47	1.37	0.15	61.20	73.20	68.20	8.49	10.9	34.6	24.55	5.89
20-40		5.13	4.92	5.03	0.56	34.40	45.40	39.90	11.31	1.17	1.35	1.26	0.13	59.90	65.60	63.75	4.03	9.8	29.3	22.61	5.33
40-60		4.79	4.81	4.80	0.72	27.50	43.60	35.55	14.92	1.04	1.33	1.18	0.21	48.40	62.40	56.40	9.90	6.6	25.8	19.76	4.79
60-100		4.12	4.76	4.44	1.16	24.30	42.50	33.40	16.40	0.93	1.27	1.10	0.24	41.30	54.30	48.80	9.19	5.9	22.3	17.14	4

4.4.4 Microbial Biomass Carbon (mg/kg)

The value of Microbial Biomass Carbon in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 70.40 to 90.00, 56.80 to 78.60, 45.90 to 70.10 and 37.90 to 61.90, 70.6 to 135.5, 61.4 to 126.0 and 56.4 to 108.0, 47.5 to 92.0, 92.40 to 141.10 and 82.30 to 136.60, 72.40 to 128.20, 60.20 to 125.30 and 75.60 to 138.10, 58.90 to 121.30, 36.60 to 88.60 and 24.40 to 67.70, 56.20 to 70.30, 54.40 to 58.80 and 48.90 to 50.30, 33.40 to 44.80, 61.20 to 73.20 and 59.90 to 65.60, 48.40 to 62.40 and 41.30 to 54.30 under agriculture land, horticulture land, forest land, grassland land, eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 83.86, 67.74, 98.90, 51.51 under agriculture, 104.05, 94.7, 83.2, 70.75 under horticulture, 117.75, 110.45, 101.30, 93.75 under forest, 112.01, 91.62, 68.71, 49.30 under grassland, 64.25, 57.60, 50.60, 20.10 under eroded, 68.20, 63.75, 56.40, 48.80 under barren land uses. In the surface soils, the MBC in the order of forest land land use system > grass land land use system > horticulture land use system > agriculture land use system > barren land land use system > eroded soils, respectively.

4.4.5 Total Carbon (gm/kg)

The value of Total Carbon in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were from 20.60 to 29.50, 19.30 to 26.40, 21.90 to 31.30 and 17.30 to 25.20, 11.4 to 43.2, 9.2 to 42.4 and 9.0 to 41.9, 8.9 to 39.8, 21.20 to 44.40 and 18.30 to 42.30, 16.60 to 37.30, 14.90 to 37.50 and 16.80 to 48.30, 14.20 to 36.30, 12.60 to 34.10 and 11.70 to 32.70, 16.60 to 25.30, 15.40 to 23.40 and 19.20 to 29.30, 11.60 to 22.40, 10.09 to 34.6 and 9.8 to 29.3, 6.6 to 25.8 and 5.9 to 22.3 under agriculture land, horticulture land, forest land, grassland , eroded land and barren land respectively. The mean values in 0-20 cm, 20-40 cm, 40-60 cm and 60-100 cm soil depth were 25.05, 22.85, 26.60, 21.25 under agriculture, 27.03, 25.08, 25.45, 24.35 under horticulture, 33.56, 30.07, 28.00, 25.73 under forest, 32.54, 29.33, 27.07, 24.65 under grassland, 20.95, 19.40, 24.25, 17.00 under eroded, 24.55, 22.61, 19.76, 17.14 under barren land uses. In the surface soils, the TC in the order of forest land land use system > grass land land use system > horticulture land use system > agriculture land use system > barren land land use system > eroded soils, respectively.

Table-9. Correlation co-efficient between soil properties and available nutrients in surface soils (0-20 cm) in agriculture land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	0.211	-0.072	-0.031	0.275	0.009	0.103	-0.115	-0.076
WHC(%)	0.127	-0.099	-0.125	-0.030	0.004	0.099	-0.036	0.083
Sand(%)	-0.446*	0.215	-0.393	-0.332	-0.517**	-0.370	0.004	-0.208
Silt(%)	-0.239	-0.238	-0.268	-0.163	0.017	-0.177	-0.192	0.108
Clay(%)	0.514**	-0.065	0.483*	0.375	0.444*	0.416*	0.096	0.126
pH	0.431*	0.221	0.584**	0.451*	0.333	0.242	-0.112	0.436*
EC(dS/m)	0.076	0.031	-0.101	0.195	0.193	-0.110	-0.197	0.089
CEC (Cmol/kg)	0.308	0.032	0.483*	-0.038	-0.095	0.307	0.394	-0.056
CaCO ₃ (%)	0.409*	0.487*	0.377	0.422*	0.392	0.367	0.039	0.211
CEC(Cmol P ⁺ /kg ¹)	-0.154	0.143	-0.114	-0.185	-0.224	-0.298	0.080	-0.335
Exch. Mg (cmol/kg)	0.207	0.415*	-0.018	-0.228	0.100	0.135	-0.376	-0.015
Exch. Na(mg/kg)	0.316	0.107	0.265	0.347	0.454*	0.372	-0.060	0.423*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Relationship between soil properties and available nutrients

Surface soils (0-20 cm)

The data presented in table 11 showed the relationship between available nutrients and soil properties of surface (0-20 cm) soils in agriculture land use system. The available N was positively correlated with clay ($r= 0.514^{**}$), pH ($r= 0.431^{*}$) and CaCO₃ ($r= 0.409^{*}$) whereas negatively correlated with sand content ($r= - 0.446^{*}$). The available P was positively correlated with CaCO₃ ($r= 0.487^{*}$) and exchangeable magnesium ($r= 0.415^{*}$). The available K was positively and significantly correlated with clay ($r= 0.483^{*}$), pH ($r= 0.584^{*}$) and CEC ($r= 0.483^{*}$). The available Sulphur was positively correlated with pH ($r= 0.451^{*}$) and CaCO₃ ($r= 0.422^{*}$). The available Fe was positively and significantly correlated with sand ($r= 0.517^{**}$), clay ($r= 0.444^{*}$) and exchangeable sodium ($r= 0.454^{*}$). The available Cu was positively correlated with clay ($r= 0.416^{*}$). The available Zn was positively correlated sand, CEC, calcium

carbonate and exchangeable calcium. The available Mn was positively correlated with pH ($r = 0.436^*$) and exchangeable sodium ($r = 0.423^*$).

Table-10. Correlation co-efficient between soil properties and available nutrients in Sub-surface soils (20-40 cm) in agriculture land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	0.208	-0.013	0.001	0.306	-0.079	0.029	-0.057	-0.05
WHC(%)	0.221	-0.07	0.043	0.111	0.08	0.115	-0.077	0.202
SAND(%)	-.589**	-0.129	-.462*	-.411*	-.608**	-.599**	0.059	-.437*
SILT(%)	.472*	0.145	0.343	0.276	.516**	.476*	-0.231	0.277
CLAY(%)	.435*	0.066	0.361	0.342	.428*	.446*	0.088	0.376
pH	.464*	0.281	.613**	.403*	.418*	0.381	-0.37	.418*
EC(dS/m)	0.327	-0.153	0.344	.484*	.489*	.436*	-0.122	.818**
CEC(Cmol P ⁺ /kg ¹)	0.289	0.094	.475*	0.036	-0.084	0.175	0.348	0.057
CaCO ₃ (%)	0.347	0.278	0.148	0.332	0.387	0.345	-0.051	-0.003
Exch. Ca (cmol/kg)	0.046	0.177	0.07	-0.073	-0.055	-0.199	.445*	-0.265
Exch. Mg (cmol/kg)	0.174	0.267	-0.031	0.038	0.12	0.114	-.449*	-0.183
Exch. Na(mg/kg)	0.386	0.082	0.331	0.351	.538**	.481*	-0.165	.479*

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Relationship between soil properties and available nutrients

Subsurface soils (20-40 cm)

The data presented in table 12 revealed the relationship between available nutrients and soil properties of sub surface (20-40 cm) soil in agriculture land use system. The available N was positively correlated with silt ($r = 0.472^*$), clay ($r = 0.435^*$) and pH ($r = 0.464^*$) whereas negatively with sand content ($r = -0.589^{**}$). The available P was positively correlated with silt, clay, CEC, CaCO₃ exch. Mg and exchangeable Na content. The available K content was positively and significantly correlated with pH ($r = 0.613^{**}$) and CEC ($r = 0.475^*$) content. Sulphur was positively correlated with sand ($r = -0.462^*$). The available S was positively and significantly correlated with pH ($r = 0.403^*$) and EC ($r = 0.484^*$) whereas negatively with sand ($r = -0.411^*$). The available Fe was positively correlated with silt ($r = 0.516^{**}$), clay ($r = 0.428^*$), pH ($r = 0.418^*$) and EC ($r = 0.489^*$) whereas negatively correlated with sand ($r = -0.608^{**}$). The available Cu was positively correlated with silt ($r = 0.476^*$), clay ($r = 0.446^*$) and EC ($r = 0.436^*$) and Na ($r = 0.481^*$) whereas negatively co-related with

sand ($r = -0.599^{**}$) content. The Zn was positively correlated with Ca ($r = 0.445^*$) whereas negatively co-related with exch. Mg ($r = -0.449^*$) content. The Mn was positively correlated with pH ($r = 0.418^*$), EC ($r = 0.818^{**}$) and Na ($r = 0.479^*$) whereas negatively with sand ($r = -0.437^*$).

Table-11. Correlation co-efficient between soil properties and available nutrients in Sub-surface soils (40-60 cm) in agriculture land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	0.031	-0.012	-0.069	-0.226	0.167	-0.228	-0.16	-0.079
WHC(%)	0.1	0.375	-0.002	0.122	0.356	0.281	0.211	-0.006
SAND(%)	-.695 ^{**}	-.460 [*]	-0.149	-.462 [*]	-0.139	-.429 [*]	-.538 ^{**}	0.171
SILT(%)	.645 ^{**}	0.29	0.048	0.231	0.065	0.252	0.309	-0.286
CLAY(%)	.531 ^{**}	.417 [*]	0.157	.450 [*]	0.138	.399 [*]	.504 [*]	-0.068
pH	.513 ^{**}	.420 [*]	0.304	.716 ^{**}	0.135	0.205	0.228	-0.251
EC(dS/m)	0.273	.677 ^{**}	0.341	.527 ^{**}	.709 ^{**}	.610 ^{**}	.609 ^{**}	-0.034
CEC(Cmol P ⁺ /kg ¹)	-0.069	0.378	0.185	.408 [*]	0.176	0.184	0.264	-0.076
CaCO ₃ (%)	-0.069	0.288	0.037	.462 [*]	0.035	0.048	0.165	0.285
Exch. Ca (cmol/kg)	-0.183	0.354	0.269	0.172	0.352	0.296	0.26	-0.151
Exch. Mg (cmol/kg)	-0.149	0.011	0.182	-0.007	-0.127	-0.119	-0.211	0.388
Exch. Na(mg/kg)	0.026	0.166	0.238	0.006	0.019	0.092	0.075	-.479 [*]

^{**}. Correlation is significant at the 0.01 level (2-tailed).

^{*}. Correlation is significant at the 0.05 level (2-tailed).

Relationship between soil properties and available nutrients

Subsurface soils (40-60 cm)

The data presented in table 13 depicted the relationship between available nutrients with soil properties of sub surface (40-60 cm) soil in agriculture land use systems. The available N was positively correlated with silt ($r = 0.645^{**}$), clay ($r = 0.531^{**}$) and pH ($r = 0.513^{**}$) whereas negatively with sand ($r = -0.695^{**}$). The available P was positively correlated with clay ($r = 0.417^*$), pH ($r = 0.420^*$), EC ($r = 0.677^{**}$) whereas negative related with sand ($r = -0.460^*$). The available K was positively and significantly correlated with silt, clay pH, EC, CEC, CaCO₃ exch. Calcium, exch. Mg, exch. sodium whereas negatively with BD, WHC and Sand. The available S was positively and significantly correlated with clay ($r = 0.450^*$) and pH ($r = 0.716^{**}$), EC ($r = 0.527^{**}$), CEC ($r = 0.408^*$) and CaCO₃ ($r = 0.462^*$) whereas negatively co-related with sand content ($r = -0.462^*$). The available Fe was positively

correlated with EC ($r = 0.709^{**}$). The available Cu was positively correlated EC ($r = 0.610^{**}$), clay ($r = 0.399^*$) whereas negatively with sand ($r = -0.429^*$) content. The available Zn was positively correlated with clay ($r = 0.504^*$) and EC ($r = 0.609^{**}$) whereas negatively with Sand content ($r = -0.538^{**}$). The available Mn was positively correlated with exch. sand and CaCO_3 and negatively with Na ($r = -0.479^*$).

Table-12. Correlation co-efficient between soil properties and available nutrients in Sub-surface soils (60-100 cm) in agriculture land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	0.032	0.016	-0.041	0.032	-0.229	-0.226	-0.186	-0.047
WHC(%)	0.374	0.161	0.223	0.381	0.272	0.394	-0.077	0.094
SAND(%)	-.471*	-0.029	-.538**	-0.2	-0.348	-0.382	0.038	-0.318
SILT(%)	0.331	-0.083	0.289	0.231	0.26	.530**	-0.243	0.366
CLAY(%)	.421*	0.082	.529**	0.131	0.304	0.201	0.083	0.208
pH	0.305	0.247	.534**	0.005	0.069	0.284	-0.392	.412*
EC(dS/m)	.643**	.546**	.546**	0.252	.552**	.601**	0.044	.574**
CEC(Cmol P ⁺ /kg ¹)	0.22	0.247	.459*	0.065	0.018	-0.083	0.191	0.099
CaCO ₃ (%)	0.145	.437*	0.186	0.228	0.084	0.021	0.042	-0.082
Exch. Ca (cmol/kg)	-0.101	0.214	-0.015	-0.134	-0.106	-0.364	0.353	-.418*
Exch. Mg (cmol/kg)	0.19	0.317	0.036	0.171	0.089	0.075	-0.391	-0.242
Exch. Na(mg/kg)	.460*	0.177	0.382	0.293	.598**	.542**	-0.258	.491*

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Relationship between soil properties and available nutrients

Subsurface soils (60-100 cm)

The data presented in table 14 showed the relationship between available nutrients and soil properties of sub surface (60-100 cm) soils in agriculture land use systems. The available N was positively correlated with clay ($r = 0.421^*$), EC ($r = 0.643^{**}$) and Na ($r = 0.460^*$) whereas negatively with sand ($r = -0.471^{**}$). The available P was positively correlated with EC ($r = 0.546^{**}$), and CaCO_3 ($r = 0.437^*$). The available K content was positively and significantly correlated with clay ($r = 0.529^{**}$), pH ($r = 0.534^{**}$), EC ($r = 0.546^{**}$) and CEC ($r = 0.459^*$), whereas negatively co-related Sand ($r = -0.538^{**}$). The available S was positively and significantly correlated with BD, WSC, Silt, clay, pH, EC, CEC, CaCO_3 exch. Mg and exch. Na

whereas negatively co-related with sand content and exch. Ca. The available Fe was positively correlated with EC ($r= 0.552^{**}$) and Na ($r= 0.598^{**}$). The available Cu was positively correlated silt ($r= 0.530^{**}$), EC ($r= 0.601^{**}$) and Na ($r= 0.542^{**}$). The Zn was positively correlated with clay, EC, CEC, CaCO_3 exch. Ca whereas negatively with BD, WHC, Silt, pH, exch. Mg and exch. Na. The available Mn was positively with pH ($r= 0.412^*$), E ($r= 0.574^{**}$) and exch. Na ($r= 0.491^*$) whereas negatively correlated exch. Na ($r= -0.418^*$).

Table-13. Correlation co-efficient between soil properties and available nutrients in surface soils (0-20 cm) in horticulture land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	0.098	0.056	0.16	-0.209	0.092	-0.101	-0.308	-0.193
WHC(%)	0.035	0.502	0.228	0.021	0.417	-0.039	0.545	0.21
SAND(%)	-0.594	-0.13	-0.438	-0.086	-0.616	-0.476	0.063	0.216
SILT(%)	.664*	0.319	0.557	0	0.559	0.556	-0.07	0.106
CLAY(%)	0.296	-0.178	0.123	0.176	0.486	0.202	-0.031	-0.592
pH	-0.261	0.013	-0.295	0.526	-0.224	0.05	0.247	-0.024
EC(dS/m)	0.012	-0.228	-0.122	-0.305	-0.129	0	-0.142	0.332
CEC(Cmol P ⁺ /kg ¹)	0.528	0.38	0.483	-0.428	0.304	0.595	-0.193	0.243
CaCO_3 (%)	0.496	.694*	0.579	-0.084	.677*	0.507	-0.183	0.033
Exch. Ca(cmol/kg)	-0.029	-0.136	0.172	0.053	-0.288	-0.332	-0.113	0.171
Exch. Mg(cmol/kg)	0.272	0.118	0.356	0.338	0.169	0.067	0.274	-0.151
Exch. Na(mg/kg)	0.386	0.395	0.294	-0.313	0.216	.662*	0.292	0.314

Relationship between soil properties and available nutrients

Surface soils (0-20 cm)

The data presented in table 23 indicated the relationship between available nutrients with soil properties of surface (0-20 cm) soils in horticulture use systems. The available N was positively correlated with Silt ($r= 0.664^*$). The available P was positively correlated with CaCO_3 ($r= 0.694^{**}$). The available K content was positively and significantly correlated with BD, WHC, Silt, clay, CEC, CaCO_3 , exch. Ca, exch. Mg, exch. Na whereas negatively correlated with sand, pH and EC. The

available S content was positive and significant correlated with WHC, Silt, Clay, pH, exch. Ca, exch. Mg whereas negatively correlated to BD, Sand, EC, CEC, CaCO₃ and exch. Na. The available Fe content was positively correlated with CaCO₃ ($r = 0.677^*$). The available Cu was positively correlated exch. Na ($r = 0.662^*$). The available Zn was positively correlated with WHC, Sand, Clay, pH, exch. Mg and exch. Na whereas negatively correlated with BD, Silt, EC, CEC, CaCO₃ and exch. Ca. The available Mn was positively correlated with WHC, Silt, Clay, pH, EC, CEC, CaCO₃, exch. Ca and exch. Na whereas negatively correlated with BD, Sand and exch. Mg.

Table-14. Correlation co-efficient between soil properties and available nutrients in surface soils (20-40 cm) in horticulture land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	0.095	0.106	0.188	0.183	0.229	-0.138	0.034	-0.368
WHC(%)	0.043	0.322	0.18	0.245	0.368	-0.303	0.574	0.17
SAND(%)	0.012	-0.12	0.121	-0.607	-0.306	0.03	-0.297	0.242
SILT(%)	-0.506	-0.368	-0.575	-0.242	-0.271	-0.291	-0.347	-0.191
CLAY(%)	0.374	0.415	0.307	.860**	0.548	0.19	0.596	-0.122
pH	-0.208	0.436	-0.164	.708*	0.31	-0.103	0.412	-0.014
EC(dS/m)	-0.121	-0.509	-0.287	-0.156	-0.544	0.159	-0.265	-0.107
CEC(Cmol P ⁺ /kg ¹)	0.552	0.356	0.515	-0.322	0.228	.802**	-0.274	0.113
CaCO ₃ (%)	0.466	0.599	0.61	0.036	0.63	0.421	-0.301	-0.072
Exch. Ca(cmol/kg)	-0.029	-0.385	0.091	-0.151	-0.583	-0.193	-0.109	0.18
Exch. Mg(cmol/kg)	0.361	0.031	0.415	0.402	0.095	0.126	0.197	-0.254
Exch. Na(mg/kg)	0.308	0.421	0.262	-0.177	0.103	.695*	0.189	0.243

Relationship between soil properties and available nutrients

Subsurface soils (20-40 cm)

The data presented in table 24 showed that relationship between available nutrients with soil properties of sub surface (20-40 cm) soils in horticulture use systems. The available N was positively correlated with BD, WHC, Clay, CEC, CaCO₃, exch. Mg, exch. Na whereas negatively correlated to Silt, pH, EC and exch. Ca. The available P was positively correlated with BD, WHC, Silt, Clay, pH, CEC, CaCO₃, exch. Mg, exch. Na whereas negatively correlated with Sand, EC and exch. Ca

The available K content was positively and significantly correlated with BD, WHC, Sand, Silt, Clay, CEC, CaCO₃, exch. Ca, exch. Mg and exch. Na whereas negatively correlated with Silt and pH. The available S was positively and significantly correlated with clay ($r = 0.860^{**}$) and pH ($r = 0.708^*$). The available Fe content was positively correlated with Clay ($r = 0.648^*$). The available Cu was positively correlated exch. CEC ($r = 0.802^{**}$) and exch Na ($r = 0.695^*$). The available Zn was positively correlated with Clay ($r = 0.696^*$) whereas negatively correlated with. The available Mn was positively correlated with Clay ($r = 0.622^*$).

Table-15. Correlation co-efficient between soil properties and available nutrients in Subsurface soils (40-60 cm) in horticulture land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	0.238	0.165	0.313	-0.197	0.315	-0.104	0.002	-0.38
WHC(%)	0.042	0.151	0.161	-0.043	0.263	-0.353	0.501	0.278
SAND(%)	-0.163	-0.401	-0.118	-0.449	-0.582	-0.186	-0.539	-0.129
SILT(%)	0.173	0.119	-0.013	0.129	0.155	0.376	0.243	0.166
CLAY(%)	0.067	0.447	0.175	0.504	.665*	-0.088	0.524	0.026
pH	-0.174	0.419	0.006	.854**	0.311	0.025	0.423	-0.091
EC(dS/m)	-0.546	-0.439	-.679*	0.147	-0.398	-0.142	-0.197	-0.579
CEC(Cmol P ⁺ /kg ¹)	0.57	0.504	0.499	-0.447	0.411	.747*	-0.277	0.194
CaCO ₃ (%)	0.415	0.583	0.586	0.092	.644*	0.404	-0.313	0.076
Exch. Ca(cmol/kg)	0.029	-0.2	0.128	-0.31	-0.427	-0.143	-0.073	0.252
Exch. Mg(cmol/kg)	0.139	0.194	0.304	0.479	0.035	-0.043	0.511	-0.184
Exch. Na(mg/kg)	0.4	0.503	0.272	-0.237	0.327	.688*	0.141	0.062

Relationship between soil properties and available nutrients

Subsurface soils (40-60 cm)

The data presented in table 25 indicated the relationship between available nutrients with soil properties of sub surface (40-60 cm) soils in horticulture use systems. The available N was positively correlated with Clay ($r = 0.667^*$). The available P was positively correlated with Clay ($r = 0.747^*$) and pH ($r = 0.619^*$). The available K content was positively and significantly correlated with EC ($r = 0.679^*$). The available S was positively and significantly correlated with pH ($r = 0.845^{**}$). The available Fe content

was positively correlated with Clay ($r= 0.665^*$) and CaCO_3 ($r= 0.644^*$). The available Cu was positively correlated each. CEC ($r= 0.747^*$) and exch. Na ($r= 0.688^*$). The available Zn was positively correlated with BD, WHC, Silt, Clay, pH, exch. Mg , exch. Na whereas negatively correlated with Sand, EC, CEC, CaCO_3 , exch. Ca . The available Mn was positively correlated with WHC, Silt, Clay, CEC, CaCO_3 , exch. Ca , exch. Na whereas negatively correlated with BD, Sand, pH, EC, exch. Mg .

Table-16. Correlation co-efficient between soil properties and available nutrients in Subsurface soils (60-100 cm) in horticulture land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	0.151	-0.153	0.139	-0.087	0.287	-0.002	-0.061	-0.57
WHC(%)	0.077	0.102	0.172	-0.031	0.297	-0.365	0.389	0.378
SAND(%)	0.006	-0.238	0.142	-0.056	-0.289	-0.173	-0.261	-0.107
SILT(%)	0.264	0.333	0.155	0.128	0.161	0.351	0.225	0.274
CLAY(%)	-0.307	0.004	-0.401	-0.055	0.278	-0.12	0.162	-0.14
pH	-0.139	0.411	0.098	.715*	0.06	-0.265	0.456	0.152
EC(dS/m)	-0.501	-0.2	-0.499	0.291	-0.549	-0.157	-0.194	-0.143
CEC(Cmol P ⁺ /kg ¹)	0.549	0.429	0.451	-0.504	0.502	.845**	-0.302	0.095
CaCO ₃ (%)	0.459	.673*	.669*	-0.023	0.628	0.412	-0.33	0.107
Exch. Ca(cmol/kg)	0.093	-0.249	0.068	-0.038	-0.337	-0.03	0.029	0.072
Exch. Mg(cmol/kg)	0.005	0.142	0.182	0.59	-0.188	-0.23	0.537	-0.01
Exch. Na(mg/kg)	0.449	.716*	0.484	-0.327	0.585	.721*	0.302	0.352

Relationship between soil properties and available nutrients

Subsurface soils (60-100 cm)

The data presented in table 26 indicated the relationship between available nutrients with soil properties of sub surface (60-100 cm) soil in horticulture use systems. The available N was positively correlated with BD, WHC, Silt, Clay, pH, CEC, CaCO_3 , exch. Ca , exch. Mg and exch. Na whereas negatively correlated with Sand and EC. The available P was positively correlated with CaCO_3 ($r= 0.673^*$) and Na ($r= 0.716^*$). The available K was positively significantly correlated with CaCO_3 ($r= 0.669^*$). The available S content was positively and significantly correlated with pH ($r= 0.715^*$). The available Fe was positively correlated with pH ($r= 0.706^*$). The

available Cu was positively correlated with CEC ($r = 0.845^{**}$). The available Zn was positively correlated with pH ($r = 0.856^{**}$). The Mn was positively correlated with Clay ($r = 0.744^*$) and pH ($r = 0.652^*$).

Table-17. Correlation co-efficient between soil properties and available nutrients in Subsurface soils (0-20 cm) in forest land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	-0.059	0.403	0.01	.686*	-0.041	0.584	0.123	0.244
WHC(%)	0.322	0.353	0.079	0.261	0.468	0.178	0.266	0.508
SAND(%)	0.08	-0.02	-.664*	0.137	-0.042	-0.09	-0.305	0.014
SILT(%)	-0.323	-0.279	0.319	-0.274	-0.192	0.236	0.226	-0.285
CLAY(%)	0.093	0.355	.717*	-0.014	0.084	-0.164	0.085	0.197
pH	.964**	.659*	0.397	0.162	.869**	-0.024	0.425	.805**
EC(dS/m)	0.118	-0.293	0.013	-0.462	-0.054	-.725*	-0.433	-0.295
CEC(Cmol P ⁺ /kg ¹)	0.461	.747*	0.306	0.353	0.421	0.321	0.381	.668*
CaCO ₃ (%)	.963**	.725*	0.421	0.251	.875**	0.078	0.515	.875**
Exch. Ca(cmol/kg)	-0.255	-0.171	-0.368	-0.152	-0.076	-0.26	-0.131	-0.016
Exch. Mg(cmol/kg)	0.224	-0.066	-0.367	0.233	0.138	0.583	0.569	0.272
Exch. Na(mg/kg)	0.122	0.543	0.102	0.4	0.268	0.336	0.392	0.546

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Relationship between soil properties and available nutrients

Surface soils (0-20 cm)

The data presented in table 15 indicated the relationship between available nutrients and soil properties of surface (0-20 cm) soils in forest land use systems. The available N was positively correlated with pH ($r = 0.964^{**}$) and CaCO₃ ($r = 0.963^{**}$). The available P was positively correlated with pH ($r = 0.569^*$), CEC ($r = 0.747^*$) and CaCO₃ ($r = 0.725^*$). The available K was positively and significantly correlated with clay ($r = 0.717^*$) whereas negatively with sand ($r = -0.664^*$). The available S was positively and significantly correlated with BD ($r = 0.686^{**}$). The available Fe was positively correlated with pH ($r = 0.869^{**}$) and CaCO₃ ($r = 0.875^{**}$). The available Cu was positively correlated BD, WHC, Silt, CEC, CaCO₃, exch. Mg, exch. Na whereas

negatively with EC ($r = -0.725^*$). The Zn was positively correlated with BD, WHC, Silt, Clay, pH, CEC, CaCO_3 , exch. Mg, exch. Na whereas negatively co-related with Sand, EC and exch. Ca. The available Mn was positively correlated with pH ($r = 0.805^{**}$), CEC ($r = 0.668^*$) and exch. CaCO_3 ($r = 0.875^{**}$).

Table-18. Correlation co-efficient between soil properties and available nutrients in Subsurface soils (20-40 cm) in forest land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	-0.121	0.599	0.116	.760*	-0.034	0.449	0.043	0.162
WHC(%)	0.223	0.536	0.1	0.248	0.44	0.053	0.097	0.457
SAND(%)	0.311	0.1	-0.448	-0.167	0.089	-0.328	-0.492	0.05
SILT(%)	-0.546	-0.453	-0.133	-0.132	-0.34	0.35	0.316	-0.413
CLAY(%)	0.184	0.378	.788**	0.388	0.264	0.065	0.336	0.403
pH	.959**	0.609	0.364	0.181	.911**	0.017	0.302	.837**
EC(dS/m)	-0.172	-.634*	-0.363	-.654*	-0.319	-0.616	-0.587	-0.457
CEC(Cmol P ⁺ /kg ¹)	0.483	.750*	0.303	0.415	0.432	0.272	0.251	.671*
CaCO_3 (%)	.792**	.850**	0.418	0.601	.768**	0.5	0.557	.850**
Exch. Ca(cmol/kg)	-0.252	-0.099	-0.441	-0.197	-0.145	-0.203	-0.099	-0.044
Exch. Mg(cmol/kg)	0.297	0.179	-0.279	0.235	0.184	.677*	0.547	0.222
Exch. Na(mg/kg)	0.17	0.605	0.102	0.432	0.216	0.262	0.29	0.558

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Relationship between soil properties and available nutrients

Subsurface soils (20-40 cm)

The data presented in table 16 showed the relationship between available nutrients with soils properties of sub surface (20-40 cm) soil in forest land use systems. The available N was positively correlated with pH ($r = 0.959^{**}$), CaCO_3 ($r = 0.792^{**}$). The available P was positively correlated with CEC ($r = 0.750^*$) and CaCO_3 ($r = 0.850^{**}$) whereas negatively correlated with EC ($r = -0.634^*$). The available K was positively and significantly correlated with clay ($r = 0.788^{**}$). The available S was positively and significantly correlated with BD ($r = 0.760^*$) whereas negatively correlated with EC ($r = -0.654^*$). The available Fe content was positively correlated with pH ($r = 0.911^{**}$) and CaCO_3 ($r = 0.768^{**}$). The available Cu was positively

correlated exch. Mg ($r = 0.677^*$). The available Zn was positively correlated with BD, WHC, Silt, Clay, pH, CEC, CaCO_3 , exch. Mg, exch. Na whereas negatively with Sand, EC and exch. Ca. The available Mn was positively correlated with pH ($r = 0.837^{**}$), CEC ($r = 0.671^*$) and exch. CaCO_3 ($r = 0.850^{**}$).

Table-19. Correlation co-efficient between soil properties and available nutrients in Subsurface soils (40-60 cm) in forest land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	-0.368	0.322	0.228	0.614	-0.284	0.457	-0.109	-0.116
WHC(%)	0.197	0.619	0.305	0.365	0.419	0.128	0.136	0.465
SAND(%)	0.048	0.168	-0.377	0.026	0.006	-0.515	-.634*	0.062
SILT(%)	-0.394	-0.524	0.202	-0.251	-0.4	0.245	0.392	-0.391
CLAY(%)	0.402	0.365	0.354	0.261	0.476	0.524	0.537	0.375
pH	.943**	0.612	0.372	0.207	.845**	0.129	0.262	.851**
EC(dS/m)	0.263	-0.271	0.062	-0.477	0.037	-0.62	-0.28	-0.143
CEC(Cmol P ⁺ /kg ¹)	0.542	.653*	0.238	0.276	0.407	0.279	0.144	.660*
CaCO_3 (%)	0.548	.804**	0.098	.729*	0.584	0.58	0.189	.686*
Exch. Ca(cmol/kg)	-0.309	-0.155	-0.455	-0.37	-0.203	-0.427	-0.15	-0.167
Exch. Mg(cmol/kg)	0.172	-0.001	-0.515	-0.007	0.12	0.545	0.427	0.111
Exch. Na(mg/kg)	0.039	0.487	0.061	0.36	0.038	0.248	0.122	0.435

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Relationship between soil properties and available nutrients

Subsurface soils (40-60 cm)

The data presented in table 17 indicated the relationship between available nutrients with soils properties of sub surface (40-60 cm) soil in **forest** land use systems. The available N was positively correlated with pH ($r = 0.943^{**}$). The available P was positively correlated with CEC ($r = 0.653^*$) and CaCO_3 ($r = 0.804^{**}$). The available K was positively and significantly correlated with BD, WHC, Silt, clay, pH, EC, CEC, CaCO_3 and exch. Na whereas negatively with Sand, exch. Ca and exch. Mg. The available S was positively and significantly correlated with CaCO_3 ($r = 0.729^*$). The available Fe was positively correlated with pH ($r = 0.854^{**}$). The

available Cu was positively correlated BD, WHC, Silt, Clay, pH, CEC, CaCO₃, exch. MG and exch. Na whereas negatively with Sand, EC, exch. Ca. The Zn was positively correlated with WHC, Silt, Clay, pH, CEC, CaCO₃, exch. Mg and exch. Na whereas negatively with Sand ($r = -0.634^*$). The available Mn was positively correlated with pH ($r = 0.851^{**}$) and CaCO₃ ($r = 0.686^*$).

Table-20. Correlation co-efficient between soil properties and available nutrients in Subsurface soils (60-100 cm) in forest land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	-0.544	0.038	0.011	0.187	-0.345	0.402	-0.207	-0.121
WHC(%)	-0.035	0.578	0.229	0.382	0.359	0.211	0.128	0.471
SAND(%)	-0.152	0.106	-.697*	0.234	-0.134	-0.278	-0.583	0.058
SILT(%)	0.029	-0.359	0.413	-0.317	0.113	0.263	0.61	-0.398
CLAY(%)	0.227	0.303	.645*	0.025	0.081	0.124	0.183	0.384
pH	.902**	.692*	0.292	0.463	.795**	0.222	0.27	0.862
EC(dS/m)	-0.418	-0.625	-0.436	-0.472	-0.599	-0.585	-0.621	-0.136
CEC(Cmol/kg)	0.459	.674*	0.254	0.379	0.375	0.262	0.144	0.678
CaCO ₃ (%)	0.624	.689*	0.295	.684*	.677*	.834**	0.505	0.698
Exch. Ca(cmol/kg)	-0.423	-0.052	-0.453	-0.137	-0.149	-0.243	-0.028	-0.181
Exch. Mg(cmol/kg)	0.024	-0.073	-0.508	-0.196	0.097	0.338	0.373	0.128
Exch. Na(mg/kg)	-0.092	0.516	0.082	0.395	0.006	0.189	0.09	0.458

Relationship between soil properties and available nutrients

Subsurface soils (60-100 cm)

The data presented in table 18 indicated the relationship between available nutrients with soil properties of sub surface (60-100 cm) soils in forest land use systems. The available N was positively correlated with pH ($r = 0.902^{**}$). The available P was positively correlated with pH ($r = 0.692^*$), CEC ($r = 0.674^*$) and CaCO₃ ($r = 0.689^*$). The available K content was positively and significantly correlated with Clay ($r = 0.645^*$) whereas negatively correlated with Sand ($r = -0.697^*$). The available S was positive and significant correlated with CaCO₃ ($r = 0.684^*$). The available Fe was positively correlated with pH ($r = 0.795^{**}$) and CaCO₃ ($r = 0.677^*$). The available Cu was positively correlated CaCO₃ ($r = 0.834^{**}$). The available Zn was

positively correlated with WHC, Silt, Clay, pH, CEC, CaCO₃, exch. Mg and exch. Na whereas negatively with BD, Sand, EC and exch. Ca. The available Mn was positively correlated with pH ($r = 0.862^{**}$), CEC ($r = 0.678^{*}$) and CaCO₃ ($r = 0.698^{*}$).

Table-21. Correlation co-efficient between soil properties and available nutrients in surface soils (0-20 cm) in grassland land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	-0.242	-0.385	0.121	0.084	-0.108	-0.188	0.128	0.15
WHC(%)	0.106	-0.393	-0.104	0.231	-0.044	0.169	0.18	0.16
SAND(%)	0.272	-0.258	0.281	0.497	0.116	0	0.177	0.16
SILT(%)	.701*	0.278	0.56	0.608	.849**	0.432	-0.021	-0.188
CLAY(%)	-.651*	0.052	-0.574	-.786**	-0.607	-0.259	-0.138	-0.024
pH	0.437	-0.036	.732*	.892**	0.596	0.6	0.082	-0.335
EC(dS/m)	.866**	-0.399	0.155	.796**	.804**	0.286	0.31	0.333
CEC(Cmol P ⁺ /kg ¹)	.817**	-0.253	0.393	.922**	.861**	0.502	0.128	0.089
CaCO ₃ (%)	.711*	-0.328	.668*	.938**	.743*	0.599	0.183	0.109
Exch. Ca(cmol/kg)	-0.223	-0.03	0.199	0.239	-0.008	-0.093	0.177	-0.341
Exch. Mg(cmol/kg)	0.027	0.248	0.014	-0.324	-0.142	0.087	0.204	0.067
Exch. Na(mg/kg)	0.243	-0.384	0.511	0.263	0.379	0.368	-0.051	0.122

Relationship between soil properties and available nutrients

Surface soils (0-20 cm)

The data presented in table 19 indicated the relationship between available nutrients with soil properties of surface (0-20 cm) soils in grassland land use systems. The available N was positively correlated with Silt ($r = 0.701^{*}$), Clay ($r = 0.651^{*}$), EC ($r = 0.866^{**}$), CEC ($r = 0.817^{**}$) and CaCO₃ ($r = 0.711^{*}$). The available P was positively correlated with Silt, clay, Mg and Sodium. The available K content was positive and significant correlated with pH ($r = 0.732^{*}$) and CaCO₃ ($r = 0.668^{*}$). The available S content was positive and significant correlated with Clay ($r = 0.786^{*}$), pH ($r = 0.892^{**}$), EC ($r = 0.796^{**}$), CEC ($r = 0.922^{**}$) and CaCO₃ ($r = 0.938^{**}$). The available Fe content was positively correlated with Silt ($r = 0.849^{**}$), EC ($r = 0.804^{**}$), CEC ($r = 0.861^{**}$) and CaCO₃ ($r = 0.743^{*}$). The available Cu was positively correlated

WHC, Silt, Clay, pH, EC, CEC, CaCO₃, exch. Mg and exch. Na. The available Zn was positively correlated with BD, WHC, Sand, Clay, pH, EC, CEC, CaCO₃, exch. Mg and negatively correlated with Silt and exch. Na.. The available Mn was positively with BD, WHC, Sand, Clay, EC, CEC, CaCO₃, exch. Mg, exch. Na whereas negatively with Silt and exch. Ca.

Table-22. Correlation co-efficient between soil properties and available nutrients in Subsurface soils (20-40 cm) in grassland land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	-0.356	-0.339	0.099	-0.28	-0.186	-0.1	0.128	0.049
WHC(%)	-0.247	-0.191	-0.025	0.003	-0.157	0.504	0.027	0.01
SAND(%)	0.541	-0.078	0.329	.659*	0.345	0.338	0.082	-0.092
SILT(%)	0.226	-0.275	0.482	0.533	0.566	0.57	0.069	-0.307
CLAY(%)	-0.452	0.256	-0.546	-.752*	-0.62	-0.62	-0.096	0.288
pH	.859**	-0.28	0.54	.846**	.938**	0.144	0.038	-0.073
EC(dS/m)	.948**	-0.48	0.299	.915**	.899**	0.235	0.085	0.251
CEC(Cmol P ⁺ /kg ¹)	.823**	-0.391	0.432	.946**	.886**	0.492	0.014	0.054
CaCO ₃ (%)	0.566	-0.415	.690*	.766**	.709*	.715*	0.052	0.002
Exch. Ca(cmol/kg)	-0.26	-0.147	0.243	-0.083	0.031	0.037	0.273	-0.374
Exch. Mg(cmol/kg)	-0.017	0.348	-0.095	-0.233	-0.245	-0.162	0.167	0.146
Exch. Na(mg/kg)	0.249	-0.44	0.483	0.187	0.345	0.093	-0.104	0.117

Relationship between soil properties and available nutrients

Subsurface soils (20-40 cm)

The data presented in table 20 indicated the relationship between available nutrients with soil properties of sub surface (20-40 cm) soils in grassland land use systems. The available N was positively correlated with Clay (r= 0.752**), pH (r= 0.859**), EC (r= 0.948**), CEC (r= 0.823**). The available P was positively correlated with Clay and Mg whereas negatively correlated with BD, WSE, Sand, Silt, pH, EC, CEC, CaCO₃, exch. Ca and exch. Na. The available K content was positive and significant correlated with CaCO₃ (r= 0.690*). The available S content was positively and significantly correlated with Clay (r= 0.752*), pH (r= 0.846**), EC (r=

0.915**), CEC ($r = 0.946^{**}$) and S ($r = 0.966^{**}$). The available Fe content was positively correlated with pH ($r = 0.938^{**}$), EC ($r = 0.899^{**}$), CEC ($r = 0.886^{**}$) and CaCO_3 ($r = 0.709^*$). The Cu was positively correlated CaCO_3 ($r = 0.715^*$). The available Zn was positively correlated with BD, WHC, Silt, Clay, pH, EC, CEC, CaCO_3 , exch. Ca and exch. Mg whereas negatively with sand and exch. Na. The available Mn was positively correlated with BD, WHC, Clay, EC, CEC, CaCO_3 , exch. Mg, and exch. Na whereas negatively with Sand, Silt, pH and exch. Ca.

Table-23. Correlation co-efficient between soil properties and available nutrients in Subsurface soils (40-60 cm) in grassland land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	-0.354	-0.208	0.011	-0.063	-0.235	-0.127	0.249	0.056
WHC(%)	-0.317	-0.075	0.279	0.196	-0.032	0.572	-0.029	0.037
SAND(%)	0.192	-0.187	0.471	0.209	0.268	0.236	0.188	0.082
SILT(%)	0.198	-0.068	-0.267	0.283	0.248	0.045	0.317	-0.074
CLAY(%)	-0.402	0.269	-0.239	-0.506	-0.534	-0.298	-0.516	-0.014
pH	.676*	-0.491	0.585	.773**	.796**	0.575	0	0.071
EC(dS/m)	.924**	-0.528	0.242	.709*	.870**	0.251	-0.212	0.18
CEC(Cmol P ⁺ /kg ¹)	.796**	-0.542	0.395	.903**	.889**	0.508	-0.03	0.013
CaCO_3 (%)	.644*	-0.493	0.467	.752*	.688*	0.504	-0.045	0.188
Exch. Ca(cmol/kg)	-0.254	-0.036	0.43	0.038	0.123	-0.059	0.166	-0.359
Exch. Mg(cmol/kg)	0.005	0.328	-0.202	-0.349	-0.18	-0.194	0.004	0.244
Exch. Na(mg/kg)	0.207	-0.371	0.419	0.007	0.235	-0.048	-0.181	0.253

Relationship between soil properties and available nutrients

Subsurface soils (40-60 cm)

The data presented in table 21 indicated the relationship between available nutrients with soil properties of sub surface (40-60 cm) soils in grassland land use systems. The available N was positively correlated with pH ($r = 0.676^*$), EC ($r = 0.924^{**}$), CEC ($r = 0.796^{**}$) and CaCO_3 ($r = 0.644^*$). The available P was positively correlated with Clay and Mg whereas negatively correlated with clay and exch. Mg. In the K content was positive and significant correlated with BD, WHC, Sand, Clay, pH,

EC, CEC, CaCO₃, exch. Ca and exch. Mg whereas negatively correlated with Silt, exch. Mg. The available S content was positive and significant correlated with pH ($r=0.773^{**}$), EC ($r=0.709^{*}$), CEC ($r=0.903^{**}$) and CaCO₃ ($r=0.752^{*}$). In Fe content was positively correlated with pH ($r=0.796^{**}$), EC ($r=0.870^{**}$), CEC ($r=0.889^{**}$) and CaCO₃ ($r=0.688^{*}$). The available Cu was positively correlated WHC, Silt, Clay, pH, EC, CEC, CaCO₃ whereas negatively with BD, exch. Mg and exch. Na. The available Zn was positively correlated with BD, Sand, Silt, Clay, pH, exch. Ca and exch. Mg whereas negatively with WHC, EC, CEC, CaCO₃, exch. Na. The available Mn was positively correlated with BD, WHC, Sand, Clay, pH, EC, CEC, CaCO₃, exch. Mg and exch. Na whereas negatively with Silt and exch. Ca.

Table-24. Correlation co-efficient between soil properties and available nutrients in Subsurface soils (60-100 cm) in grassland land use systems

Soil properties	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)
BD(g/cm ³)	-0.166	-0.202	-0.046	0.069	-0.176	-0.216	0.209	0.107
WHC(%)	0.005	0.089	0.08	0.329	-0.259	0.406	0.048	0.093
SAND(%)	-0.275	-0.489	0.141	0.117	0.187	0.016	0.416	0.189
SILT(%)	0.522	0.307	0.022	-0.047	0.093	0.004	0.05	-0.301
CLAY(%)	-0.27	0.123	-0.143	-0.055	-0.252	-0.017	-0.407	0.13
pH	0.42	-0.573	0.553	.735*	.814**	0.623	0.004	-0.013
EC(dS/m)	0.386	-0.424	0.467	0.535	.906**	0.599	-0.351	0.177
CEC(Cmol P ⁺ /kg ¹)	0.43	-0.631	0.374	.725*	.930**	0.593	-0.044	0.141
CaCO ₃ (%)	0.034	-0.283	0.213	0.421	0.319	0.256	-0.318	0.414
Exch. Ca(cmol/kg)	0.157	-0.003	0.18	0.091	-0.161	-0.222	0.196	-0.402
Exch. Mg(cmol/kg)	-0.29	0.37	-0.162	-0.515	-0.383	-0.173	-0.119	0.297
Exch. Na(mg/kg)	0.005	-0.445	0.457	0.184	0.212	0.042	-0.205	0.251

Relationship between soil properties and available nutrients Subsurface soils (60-100 cm)

The data presented in table 22 indicated the relationship between available nutrients with soil properties of sub surface (60-100 cm) soils in grassland land use systems. The available N was positively correlated with WHC, Silt, Clay, pH, EC,

CEC, CaCO_3 , exch. Carbon and exch. Na whereas negatively correlated with Sand and exch. Mg. The available P was positively correlated with WHC, Silt, Clay, EC and exch. Mg and negatively correlated with BD, Sand, pH, CEC, CaCO_3 , exch. Na. The available K was positively and significantly correlated with WHC, Sand, Silt, clay, pH, CEC, CaCO_3 , exch. Mg negatively correlated with BD and exch. Mg. The available S was positively and significantly correlated with pH ($r= 0.735^*$) and CEC ($r= 0.725^*$). The available Fe was positively correlated with pH ($r= 0.814^{**}$), EC ($r= 0.906^{**}$) and CEC ($r= 0.930^{**}$). The available Cu was positively correlated WHC, Sand, Silt, Clay, pH, EC, CEC, CaCO_3 and exch. Na whereas negatively correlated with BD, exch. Ca and exch. Mg. The available Zn was positively correlated with BD, WHC, Sand, Silt, Clay, pH, EC, CEC, CaCO_3 , exch. Ca and exch. Na whereas negatively correlated with pH and exch. Ca. The available Mn was positively correlated with BD, WHC, Sand, Clay, EC, CEC, CaCO_3 , exch. Mg and exch. Na whereas negatively correlated with Silt, pH and exch. Ca.

Table-25. Correlation co-efficient between soil properties and Carbon pools in surface soils (0-20 cm) in agriculture land use system

Soil properties	Carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.086	0.003	0.286	0.086	-0.039
WHC(%)	-0.288	-0.335	0	-0.209	-0.386
SAND(%)	0.341	-0.133	-.405*	-0.277	0.049
SILT(%)	-0.106	-0.084	-0.078	-0.065	0.13
CLAY(%)	-0.244	0.16	0.395	0.277	-0.111
pH	-0.177	0.16	0.187	-0.241	-0.315
EC(dS/m)	0.178	-0.095	0.006	-0.16	0.131
CEC(Cmol P ⁺ /kg ¹)	0.567**	.503*	0.167	.547**	.466*
CaCO ₃ (%)	0.604**	.571**	0.272	0.127	0.306
Exch. Ca (cmol/kg)	0.049	-0.127	0.05	0.287	0.168
Exch. Mg (cmol/kg)	0.375	0.041	0.161	0.222	0.246
Exch. Na(mg/kg)	-0.342	0.183	0.272	0.049	-0.078

Relationship between soil properties and SOC pools

Surface soils (0-20 cm)

In surface soil properties (0-20 cm) soil in agriculture land use system, the significant and positive correlation were observed in table 27 between SOC and CEC

($r = 0.567^{**}$), SOC and CaCO_3 ($r = 0.604^{**}$), WSC and CEC ($r = 0.503^*$), WSC and CaCO_3 ($r = 0.571^{**}$), MBC and CEC ($r = 0.547^*$), TC and CEC ($r = 0.466^*$) whereas LC was negatively correlated with sand ($r = -0.405$).

Table-26. Correlation co-efficient between soil properties and Carbon pools in Subsurface soils (20-40 cm) in agriculture land use system

Soil properties	Carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.089	-0.016	0.206	0.071	-0.046
WHC(%)	-0.174	-0.106	0.114	-0.152	-0.378
SAND(%)	0.044	-0.268	-.563 ^{**}	-0.393	-0.159
SILT(%)	0.165	0.382	.421 [*]	0.31	0.259
CLAY(%)	-0.177	0.078	.437 [*]	0.294	0.023
pH	-0.082	0.32	0.293	-0.14	-0.188
EC(dS/m)	-0.283	0.297	0.202	-0.166	-0.266
CEC(Cmol P ⁺ /kg ¹)	.652 ^{**}	.487 [*]	0.162	0.31	.428 [*]
CaCO_3 (%)	.605 ^{**}	0.372	0.269	.461 [*]	.577 ^{**}
Exch. Ca (cmol/kg)	0.161	-0.123	0.148	0.297	0.223
Exch. Mg (cmol/kg)	0.238	0.114	0.216	0.248	0.171
Exch. Na(mg/kg)	-0.183	0.355	0.362	0.101	0.037

Relationship between soil properties and SOC pools

Subsurface (20-40 cm depth)

In sub surface soil properties (20-40 cm) soil in agriculture land use system, the significant and positive correlation were observed in table 28 between SOC and CEC ($r = 0.652^{**}$), SOC and CaCO_3 ($r = 0.605^{**}$), WSC and CEC ($r = 0.487^*$), WSC and CaCO_3 ($r = 0.461^*$), MBC and CaCO_3 ($r = 0.577^{**}$), ($r = 0.466^*$), TC and CEC ($r = 0.428^*$) and TC and CaCO_3 ($r = 0.461^*$) whereas LC was positively correlated with silt ($r = -0.563$) and negatively correlated with sand ($r = -0.563$).

Table-27. Correlation co-efficient between soil properties and Carbon pools in Subsurface soils (40-60 cm) in agriculture land use system

Soil properties	Carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.208	-0.052	-0.101	-0.09	-0.165
WHC(%)	0.102	0.255	0.215	0.156	-0.186
SAND(%)	-0.051	-0.337	-.464*	-.426*	-0.201
SILT(%)	0.069	.424*	0.334	0.321	0.349
CLAY(%)	0.028	0.203	0.401	0.362	0.074
pH	0.258	0.137	0.005	0.23	0.414*
EC(dS/m)	.461*	0.355	.515**	0.365	0.403
CEC(Cmol/kg)	.687**	.540**	0.289	.647**	0.216
CaCo ₃ (%)	.572**	0.097	0.333	.423*	0.339
Exch. Ca (cmol/kg)	0.145	0.076	0.172	0.337	0.117
Exch. Mg (cmol/kg)	0.266	0.258	0.139	0.226	-0.043
Exch. Na(mg/kg)	-0.048	0.23	0.328	0.197	0.274

Relationship between soil properties and SOC pools

Subsurface (40-60 cm depth)

A perusal of the correlation coefficients presented in the table 29 exhibited the relationship between SOC, WSC, LC, MBC and TC with soil properties of sub-surface (40-60 cm) soils in agriculture land use system. The SOC was positively and significantly correlated with EC ($r=0.461^*$), CEC ($r=0.687^{**}$) and CaCO₃ ($r=0.572^{**}$). Similar trends was observed in WSC with Silt ($r=0.524^*$) and CEC ($r=0.550^{**}$). The LC was positively correlated with EC ($r=0.515^{**}$) however negatively correlated with Sand ($r= -0.464^*$). The MBC was positively correlated with CEC ($r=0.647^{**}$) and CaCO₃ ($r=0.42^*$) whereas negatively correlated with Sand ($r= -0.426^*$). The TC was positively correlated with pH ($r=0.414^*$).

Table-28. Correlation co-efficient between soil properties and Carbon pools in Subsurface soils (60-100 cm) in agriculture land use system

Soil properties	Carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.309	-0.32	0.093	-0.251	-0.208
WHC(%)	0.178	-0.017	0.21	0.021	-0.32
SAND(%)	0.098	0.179	-0.282	0.296	0.148
SILT(%)	-0.245	-0.042	0.091	-.456*	-0.241
CLAY(%)	0.007	-0.505*	0.311	-0.132	-0.058
pH	0.147	-0.181	0.643**	-0.144	-0.208
EC(dS/m)	0.011	-0.295	0.322	-0.022	-0.11
CEC(Cmol P ⁺ /kg ¹)	.657**	0.274	0.167	.462*	0.21
CaCO ₃ (%)	.546**	0.064	-0.003	.459*	.485*
Exch. Ca (cmol/kg)	0.068	-0.321	0.055	0.127	0.159
Exch. Mg (cmol/kg)	0.332	-0.028	0.023	0.049	0.057
Exch. Na(mg/kg)	-0.014	-0.071	0.233	0.007	0.13

Relationship between soil properties and SOC pools

Subsurface (60-100 cm depth)

A perusal of the correlation coefficients presented in the table 30 exhibited the relationship between SOC, WSC, LC, MBC, TC and soil properties of sub-surface (60-100 cm) soil in agriculture land use system. The SOC was positively and significantly correlated with CEC ($r=0.657^{**}$) and CaCO₃ ($r= 0.546^{**}$). Similar trends were observed in WSC with Clay ($r= 0.505^{*}$). The LC was positively correlated with pH ($r= 0.643^{**}$). The MBC was positively correlated with CEC ($r=0.464^{*}$) and CaCO₃ ($r=0.459^{*}$) whereas negatively correlated with silt ($r= - 0.456^{*}$). The TC was positively correlated with CaCO₃ ($r=0.485^{*}$).

Table-29. Correlation co-efficient between soil properties and carbon pools in surface soils (0-20 cm) in horticulture land use system

soil properties	Carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.195	0.336	0.191	0.286	-0.068
WHC(%)	0.352	0.095	0.478	0.219	0.292
SAND(%)	-.751*	-0.423	-0.445	-0.366	-.740*
SILT(%)	0.521	0.59	0.55	0.497	.811**
CLAY(%)	.818**	0.046	0.148	0.059	0.391
pH	0.273	-0.282	-0.075	-0.251	-0.025
EC(dS/m)	-0.046	-0.124	-0.223	-0.101	0.122
CEC(Cmol P ⁺ /kg ¹)	-0.247	0.619	0.381	.633*	0.422
CaCO ₃ (%)	0.523	.739*	.853**	.884**	.842**
Exch. Ca(cmol/kg)	-0.443	-0.163	-0.282	-0.348	-0.303
Exch. Mg(cmol/kg)	0.324	0.093	0.254	-0.078	0.22
Exch. Na(mg/kg)	-0.372	0.403	0.249	0.424	0.192

Relationship between soil properties and SOC pools

Surface (0-20 cm depth)

A perusal of the correlation coefficients presented in the table 39 exhibited the relationship between SOC, WSC, LC, MBC, TC with soil properties of surface (0-20 cm) soils in horticulture use system. The SOC was positively and significantly correlated with Clay ($r=0.818^{**}$) whereas negatively correlated with Sand ($r= -0.751^{*}$). Similar trends was observed in WSC with CaCO₃ ($r= 0.739^{*}$). The LC was positively and significantly correlated with CaCO₃ ($r=0.853^{**}$). The MBC was positively and significantly correlated with CEC ($r=0.633^{*}$) and CaCO₃ ($r=0.884^{**}$). The TC was positively and significantly correlated with Silt ($r=0.811^{**}$) and CaCO₃ ($r=0.842^{**}$) whereas negatively correlated with Sand ($r= -0.740^{**}$).

Table-30. Correlation co-efficient between soil properties and carbon pools in Subsurface soils (20-40 cm) in horticulture land use system

soil properties	carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.122	0.236	0.177	-0.013	-0.066
WHC(%)	0.45	0.097	0.124	0.096	0.3
SAND(%)	-0.586	0.092	0.143	0.093	-0.2
SILT(%)	0.287	-0.426	-0.371	-0.177	-0.117
CLAY(%)	0.631*	0.224	0.125	0.033	0.312
pH	0.887**	-0.146	-0.045	0.623*	0.112
EC(dS/m)	-0.134	-0.349	-0.418	0.013	-0.237
CEC(Cmol P ⁺ /kg ¹)	-0.16	0.547	0.556	0.283	0.393
CaCO ₃ (%)	0.588	.733*	.856**	0.378	.790**
Exch. Ca(cmol/kg)	-0.545	-0.199	-0.184	-0.006	-0.402
Exch. Mg(cmol/kg)	0.335	0.234	0.149	0.332	0.282
Exch. Na(mg/kg)	-0.343	0.253	0.252	0.006	0.163

Relationship between soil properties and SOC pools

Subsurface (20-40 cm depth)

A perusal of the correlation coefficients presented in the table 40 exhibited the relationship between SOC, WSC, LC, MBC, TC with soil properties of sub-surface (20-40 cm) soils in horticulture use system. The SOC was positively and significantly correlated with Clay ($r=0.631^*$) and pH ($r=0.887^{**}$). Similar trends was observed in WSC with CaCO₃ ($r= 0.733^*$). The LC was positively and significantly correlated with CaCO₃ ($r=0.856^{**}$). The MBC was positively and significantly correlated with pH ($r=0.623^*$). The TC was positively and significantly correlated with CaCO₃ ($r=0.790^{**}$).

Table-31. Correlation co-efficient between soil properties and carbon pools in Subsurface soils (40-60 cm) in horticulture land use system

soil properties	carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.07	0.266	0.25	-0.145	0.026
WHC(%)	0.431	0.116	0.014	0.16	0.26
SAND(%)	-.782**	-0.214	-0.223	-0.462	-0.562
SILT(%)	0.532	0.139	0.105	0.505	0.415
CLAY(%)	0.895**	0.669*	0.613*	0.677*	0.598*
pH	0.684*	0.021	0.209	0.211	0.29
EC(dS/m)	-0.198	-0.63	-0.452	-0.262	-0.478
CEC(Cmol P ⁺ /kg ¹)	-0.249	0.497	0.499	0.073	0.382
CaCO ₃ (%)	0.526	.700*	.861**	0.589	.774**
Exch. Ca(cmol/kg)	-.650*	-0.156	-0.287	-0.397	-0.358
Exch. Mg(cmol/kg)	0.383	0.135	0.118	0.203	0.209
Exch. Na(mg/kg)	-0.217	0.253	0.243	-0.097	0.205

Relationship between soil properties and SOC pools

Subsurface (40-60 cm depth)

A perusal of the correlation coefficients presented in the table 41 exhibited that relationship between SOC, WSC, LC, MBC, TC with soil properties of sub-surface (40-60 cm) soils in horticulture use system. The SOC was positively and significantly correlated with Clay ($r=0.895^{**}$) and pH ($r=0.684^{*}$) whereas negatively correlated with Sand ($r= - 0.782^{**}$) and exch. Ca ($r= - 0.650^{*}$). Similar trends was observed in WSC with Clay ($r= 0.669^{*}$) and CaCO₃ ($r=0.700^{*}$). The LC was positively and significantly correlated with Clay ($r=0.613^{*}$) and CaCO₃ ($r=0.861^{**}$). The MBC was positively and significantly correlated with Clay ($r=0.677^{*}$). The TC was positively and significantly correlated with Clay ($r=0.598^{*}$) and CaCO₃ ($r=0.774^{**}$).

Table-32. Correlation co-efficient between soil properties and carbon pools in Subsurface soils (60-100 cm) in horticulture land use system

soil properties	carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.163	0.13	0.15	0.005	-0.141
WHC(%)	0.45	0.179	0.093	0.386	0.338
SAND(%)	-0.495	-0.039	-0.131	-0.366	-0.397
SILT(%)	0.572	0.292	0.372	0.545	0.612
CLAY(%)	0.142	-0.267	-0.212	-0.032	-0.059
pH	0.544	0.04	0.106	-0.006	0.264
EC(dS/m)	-0.306	-0.58	-0.477	-0.402	-0.461
CEC(Cmol P ⁺ /kg ¹)	-0.139	0.419	0.393	-0.038	0.367
CaCO ₃ (%)	.660*	.731*	.797**	0.621*	.826**
Exch. Ca(cmol/kg)	-0.569	-0.176	-0.297	-0.283	-0.393
Exch. Mg(cmol/kg)	0.278	0.099	0.186	0.171	0.13
Exch. Na(mg/kg)	-0.025	0.394	0.373	-0.147	0.438

Relationship between soil properties and SOC pools

Subsurface (60-100 cm depth)

A perusal of the correlation coefficients presented in the table 42 exhibited the relationship between SOC, WSC, LC, MBC, TC with soils properties of sub-surface (60-100 cm) soil in grassland use system. The SOC was positively and significantly correlated with CaCO₃ (r=0.660*). Similar trends was observed in WSC with CaCO₃ (r= 0.731*). The LC was positively and significantly correlated with CaCO₃ (r=0.797**). The MBC was positively and significantly correlated with CaCO₃ (r=0.621*). The TC was positively and significantly correlated with CaCO₃ (r=0.826**).

Table-33. Correlation co-efficient between soil properties and Carbon pools in surface soils (0-20 cm) in grassland land use system

Soil properties	Carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	0.269	0.226	0.2	0.27	0.278
WHC(%)	0.307	0.538	0.512	0.528	0.447
SAND(%)	0.041	-0.127	0.166	0.047	0.159
SILT(%)	-0.202	-0.223	-0.373	-0.256	-0.255
CLAY(%)	0.07	0.336	0.124	0.144	0.046
pH	0.592	0.614	.952**	.898**	.650*
EC(dS/m)	-0.096	-0.287	-0.038	-0.29	-0.369
CEC(Cmol P ⁺ /kg ¹)	0.306	0.524	0.63	.714*	.647*
CaCO ₃ (%)	.662*	.679*	.961**	.939**	.730*
Exch. Ca (cmol/kg)	-0.303	0.173	-0.267	-0.177	0.004
Exch. Mg (cmol/kg)	.760*	-0.03	0.202	0.183	0.56
Exch. Na(mg/kg)	0.085	0.581	0.243	0.426	0.456

Relationship between soil properties and SOC pools

Surface Soil (0-20 cm depth)

A perusal of the correlation coefficients presented in the table 31 exhibited the relationship between SOC, WSC, LC, MBC, TC with soils properties of (0-20 cm) soil in grassland land use system. It is exhibited the SOC was positively and significantly correlated with CaCO₃ (r= 0.662*) and exch. Mg (r=0.760*). Similar trends was observed in WSC with CaCo3 (r= 0.679*). The LC was positively correlated with pH (r= 0.952**) and CaCo3 (r=0.961**). The MBC was positively correlated with pH (r=0.898**), CEC (r=0.714*) and CaCO₃ (r=0.939**). The TC was positively and significantly correlated with pH (r=0.650*), CEC (r=0.647*) and CaCO₃ (r=0.730*).

Table-34. Correlation co-efficient between soil properties and Carbon pools in Subsurface soils (20-40 cm) in grassland land use system

Soil properties	Carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm³)	0.282	0.308	0.05	0.308	0.385
WHC(%)	0.225	0.537	0.346	0.397	0.428
Sand (%)	0.219	-0.037	0.328	0.326	0.406
Silt(%)	-0.285	-0.416	-.669*	-0.595	-0.453
Clay (%)	0.016	0.528	0.302	0.22	-0.057
pH	.683*	0.613	.958**	.881**	.751*
EC(dS/m)	-0.496	-0.493	-0.261	-0.279	-0.326
CEC(Cmol P⁺/kg¹)	0.431	0.614	0.597	.664*	.665*
CaCO₃(%)	.897**	.661*	.790**	.815**	.839**
Exch. Ca (cmol/kg)	-0.328	0.143	-0.223	-0.258	-0.184
Exch. Mg (cmol/kg)	.734*	-0.055	0.032	0.075	0.427
Exch. Na(mg/kg)	0.152	.665*	0.253	0.37	0.4

Relationship between soil properties and SOC pools

Subsurface (20-40 cm depth)

A perusal of the correlation coefficients presented in the table 32 exhibited the relationship between SOC, WSC, LC, MBC with soil properties of sub-surface (20-40 cm) soils in grassland land use system. The SOC was positively and significantly correlated with pH ($r=0.683^*$), CaCO_3 ($r=0.897^{**}$) and exch. Mg ($r=0.734^*$). Similar trends was observed in WSC with CaCO_3 ($r=0.661^*$) and exch. Na ($r=0.665^*$). The LC was positively correlated with pH ($r=0.958^{**}$) and CEC ($r=0.790^{**}$) whereas negatively correlated with Silt ($r=-0.669^*$). The MBC was positively and significantly correlated with pH ($r=0.881^{**}$), CEC ($r=0.664^{**}$) and CaCO_3 ($r=0.815^{**}$). The TC was positively and significantly correlated with pH ($r=0.751^*$), CEC ($r=0.665^*$) and CaCO_3 ($r=0.839^{**}$).

Table-35. Correlation co-efficient between soil properties and Carbon pools in Subsurface soils (40-60 cm) in grassland land use system

Soil properties	Carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm³)	0.164	-0.091	-0.22	-0.066	0.025
WHC(%)	0.333	0.522	0.304	0.532	0.407
SAND(%)	-0.272	0.202	0.12	0.141	0.137
SILT(%)	-0.261	-0.473	-0.517	-0.521	-0.509
CLAY(%)	.751*	0.252	0.435	0.406	0.399
pH	0.63	.673*	.892**	.905**	.855**
EC(dS/m)	-0.152	-0.088	0.252	-0.019	-0.181
CEC(Cmol P⁺/kg¹)	0.495	0.518	.780**	0.612	.761*
CaCo₃(%)	.851**	0.592	.635*	.694*	.846**
Exch. Ca (cmol/kg)	-0.393	0.037	-0.211	-0.234	-0.283
Exch. Mg (cmol/kg)	0.535	-0.038	0.125	0.022	0.258
Exch. Na(mg/kg)	0.137	0.493	0.339	0.157	0.392

Relationship between soil properties and SOC pools

Subsurface (40-60 cm depth)

A perusal of the correlation coefficients presented in the table 33 exhibited the relationship between SOC, WSC, LC, MBC and TC with soil properties of sub-surface (40-60 cm) soils in grassland land use system. The SOC was positively and significantly correlated with Clay ($r=0.751^*$) and CaCO_3 ($r=0.851^{**}$). Similar trends was observed in WSC with pH ($r=0.673^*$). The LC was positively correlated with pH ($r=0.892^{**}$), CEC ($r=0.780^{**}$) and CaCO_3 ($r=0.635^*$). The MBC was positively correlated with pH ($r=0.905^{**}$) and CaCO_3 ($r=0.694^*$). The TC was positively and significantly correlated with pH ($r=0.855^*$), CEC ($r=0.761^*$) and CaCO_3 ($r=0.846^{**}$).

Table-36. Correlation co-efficient between soil properties and Carbon pools in Subsurface soils (60-100 cm) in grassland land use system

Soil properties	Carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.041	-0.414	-0.451	-0.296	-0.348
WHC(%)	0.236	0.512	0.314	0.553	0.154
SAND(%)	0.003	0.022	0.194	-0.022	0.035
SILT(%)	-0.045	-0.101	-0.436	-0.168	-0.214
CLAY(%)	0.058	0.1	0.256	0.267	0.232
pH	.810**	.713*	.820**	.907**	.921**
EC(dS/m)	-0.511	-0.547	-0.381	-.668*	-0.497
CEC(Cmol P ⁺ /kg ¹)	0.493	0.545	.893**	.760*	.752*
CaCO ₃ (%)	.878**	0.422	0.411	.692*	.743*
Exch. Ca (cmol/kg)	-0.332	0.162	0.118	0.002	-0.258
Exch. Mg (cmol/kg)	0.334	-0.213	-0.096	0.046	-0.013
Exch. Na(mg/kg)	0.021	0.51	0.585	0.41	0.354

Relationship between soil properties and SOC pools

Subsurface (60-100 cm depth)

A perusal of the correlation coefficients presented in the table 34 exhibited the relationship between SOC, WSC, LC, MBC, TC with soil properties of sub-surface (60-100 cm) soil in grassland land use system. The SOC was positively and significantly correlated with pH ($r=0.810^{**}$) and CaCO₃ ($r=0.878^{**}$). Similar trends was observed in WSC with pH ($r=0.713^{*}$). The LC was positively and significantly correlated with pH ($r=0.820^{**}$) and CEC ($r=0.893^{**}$). The MBC was positively correlated with pH ($r=0.907^{**}$), CEC ($r=0.760^{*}$) and CaCO₃ ($r=0.692^{*}$) whereas negatively correlated with EC ($r=-0.668^{*}$). The TC was positively and significantly correlated with pH ($r=0.921^{**}$), CEC ($r=0.752^{*}$) and CaCO₃ ($r=0.743^{*}$).

Table-37. Correlation co-efficient between soil properties and carbon pools in surface soils (0-20 cm) in forest land use system

soil properties	carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.134	0.018	0.008	-0.079	-0.034
WHC(%)	0.04	-0.042	0.21	0.03	0.061
SAND(%)	0.054	0.329	0.363	0.22	0.316
SILT(%)	0.555	.666*	0.546	.784**	.660*
CLAY(%)	-0.378	-.678*	-.636*	-.656*	-.663*
pH	0.306	0.529	0.567	0.54	0.578
EC(dS/m)	0.443	.658*	.746*	.862**	.805**
CEC(Cmol P ⁺ /kg ¹)	0.438	.729*	.777**	.867**	.859**
CaCO ₃ (%)	0.599	.761*	.879**	.777**	.767**
Exch. Ca (cmol/kg)	-0.281	-0.139	-0.171	-0.074	-0.067
Exch. Mg (cmol/kg)	0.319	-0.183	-0.041	-0.153	-0.286
Exch. Na(mg/kg)	.699*	.708*	0.598	0.463	0.485

Relationship between soil properties and SOC pools

Surface (0-20 cm depth)

A perusal of the correlation coefficients presented in the table 35 exhibited the relationship between SOC, WSC, LC, MBC, TC with soil properties of surface (0-20 cm) soils in forest land use system. The SOC was positively and significantly correlated with exch. Na ($r=0.699^*$). Similar trends was observed in WSC with EC ($r=0.658^*$), CEC ($r=0.729^*$), CaCO₃ ($r=0.761^*$) exch. Na ($r=0.708^*$) whereas negatively correlated with Clay ($r=-0.678^*$). The LC was positively and significantly correlated with EC ($r=0.746^*$), CEC ($r=0.777^{**}$) and CaCO₃ ($r=0.879^{**}$) whereas negatively correlated with clay ($r=0.636^*$). The MBC was positively and significantly correlated with Silt ($r=0.784^{**}$), EC ($r=0.862^*$), CEC ($r=0.876^*$) and CaCO₃ ($r=0.777^{**}$) whereas negatively correlated with Clay ($r=-0.656^*$). The TC was positively and significantly correlated with EC ($r=0.805^{**}$), CEC ($r=0.859^*$) and CaCO₃ ($r=0.867^{**}$) whereas negatively correlated with Clay ($r=0.663^*$).

Table-38. Correlation co-efficient between soil properties and carbon pools in Subsurface soils (20-40 cm) in forest land use system

soil properties	carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.338	-0.112	-0.091	-0.218	-0.165
WHC(%)	-0.066	-0.361	-0.093	-0.205	-0.322
SAND(%)	0.312	0.525	0.589	0.53	0.584
SILT(%)	-0.014	0.225	0.431	0.411	0.356
CLAY(%)	-0.146	-0.442	-.637*	-0.591	-0.575
pH	0.708**	.908**	.836**	.905**	.967**
EC(dS/m)	0.602	.875**	.858**	.923**	.942**
CEC(Cmol P ⁺ /kg ¹)	0.416	.745*	.846**	.872**	.865**
CaCO ₃ (%)	0.479	.633*	.871**	.741*	.671*
Exch. Ca (cmol/kg)	-0.221	-0.13	-0.075	-0.095	-0.103
Exch. Mg (cmol/kg)	0.386	-0.213	-0.123	-0.062	-0.253
Exch. Na(mg/kg)	0.555	.682*	0.516	0.312	0.451

Relationship between soil properties and SOC pools

Subsurface (20-40 cm depth)

A perusal of the correlation coefficients presented in the table exhibited the relationship between SOC, WSC, LC, MBC, TC with soil properties of sub-surface (20-40 cm) soil in forest land use system. The SOC was positively and significantly correlated with pH ($r=0.708^{**}$). Similar trends was observed in WSC with pH ($r=0.908^{**}$), EC ($r=0.875^{**}$), CEC ($r=0.745^{*}$), CaCO₃ ($r=0.633^{*}$) and exch. Na ($r=0.682^{*}$). The LC was positively and significantly correlated with pH ($r=0.836^{**}$), EC ($r=0.858^{**}$), CEC ($r=0.846^{**}$) and CaCO₃ ($r=0.871^{**}$) whereas negatively correlated with Clay ($r=-0.637^{*}$). The MBC was positively and significantly correlated with pH ($r=0.905^{**}$), EC ($r=0.923^{**}$), CEC ($r=0.872^{**}$) and CaCO₃ ($r=0.741^{*}$). The TC was positively and significantly correlated with pH ($r=0.967^{**}$), EC ($r=0.942^{**}$), CEC ($r=0.865^{**}$) and CaO₃ ($r=0.671^{*}$).

Table-39. Correlation co-efficient between soil properties and carbon pools in Subsurface soils (40-60 cm) in forest land use system

soil properties	carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.336	-0.238	-0.517	-0.356	-0.237
WHC(%)	0.113	-0.254	0.191	-0.119	-0.239
SAND(%)	.763*	0.376	0.293	0.226	0.2
SILT(%)	-0.183	-0.211	0.096	0.348	0.113
CLAY(%)	-.636*	-0.193	-0.41	-0.588	-0.326
pH	.794**	.720*	.862**	.797**	.728*
EC(dS/m)	0.552	.822**	.851**	.891**	.930**
CEC(Cmol P ⁺ /kg ¹)	0.482	.677*	.875**	.929**	.856**
CaCO ₃ (%)	0.545	0.615	.717*	.744*	.675*
Exch. Ca (cmol/kg)	-0.125	-0.08	-0.333	-0.111	-0.025
Exch. Mg (cmol/kg)	0.305	-0.153	-0.045	-0.069	-0.217
Exch. Na(mg/kg)	0.583	0.604	0.121	0.023	0.314

Relationship between soil properties and SOC pools

Subsurface (40-60 cm depth)

A perusal of the correlation coefficients presented in the table 37 exhibited the relationship between SOC, WSC, LC, MBC, TC with soil properties of sub-surface (40-60 cm) soils in forest land use system. The SOC was positively and significantly correlated with Sand ($r=0.763^*$) and pH ($r=0.794^{**}$) whereas negatively correlated with Clay ($r= - 0.636^*$). Similar trends was observed in WSC with pH ($r= 0.720^*$), EC ($r= 0.822^{**}$) and CEC ($r= 0.677^*$). The LC was positively and significantly correlated with pH ($r=0.862^{**}$), EC ($r= 0.851^{**}$), CEC ($r= 0.875^{**}$) and CaCO₃ ($r= 0.717^*$). The MBC was positively and significantly correlated with pH ($r=0.797^{**}$), EC ($r= 0.891^{**}$), CEC ($r=0.929^{**}$) and CaCO₃ ($r=0.744^{**}$). The TC was positively and significantly correlated with pH ($r=0.728^*$), EC ($r= 0.930^{**}$), CEC ($r=0.856^{**}$) and CaCO₃ ($r=0.675^*$).

Table-40. Correlation co-efficient between soil properties and carbon pools in Subsurface soils (60-100 cm) in forest land use system

soil properties	carbon pools				
	SOC(g/kg)	WSC(mg/kg)	LC(g/kg)	MBC(mg/kg)	TC(g/kg)
BD(g/cm ³)	-0.377	-0.36	-0.529	-0.357	-0.235
WHC(%)	0.074	-0.421	0.277	-0.237	-0.378
SAND(%)	0.622	0.387	-0.045	0.31	0.275
SILT(%)	0.171	0.043	0.38	0.155	0.078
CLAY(%)	-.703*	-0.376	-0.331	-0.418	-0.313
pH	.781**	.757*	.816**	.800**	.782**
EC(dS/m)	0.493	.734*	.838**	.875**	.851**
CEC(Cmol P ⁺ /kg ¹)	0.453	.684*	.818**	.896**	.863**
CaCo ₃ (%)	0.096	0.282	0.393	0.395	0.341
Exch. Ca (cmol/kg)	-0.235	-0.277	-0.487	-0.442	-0.233
Exch. Mg (cmol/kg)	0.176	-0.161	-0.097	-0.189	-0.305
Exch. Na(mg/kg)	0.611	0.525	-0.078	0.002	0.298

Relationship between soil properties and SOC pools

Subsurface (60-100 cm depth)

A perusal of the correlation coefficients presented in the table exhibited the relationship between SOC, WSC, LC, MBC, TC with soil properties of sub-surface (60-100 cm) soils in forest land use system. The SOC was positively and significantly correlated with pH ($r=0.781^{**}$) whereas negatively correlated with Clay ($r= -0.703^{*}$). Similar trends was observed in WSC with pH ($r= 0.757^{*}$), EC ($r= 0.734^{*}$) and CEC ($r= 0.664^{*}$). The LC was positively and significantly correlated with pH ($r=0.816^{**}$), EC ($r= 0.838^{**}$) and CEC ($r= 0.818^{**}$). The MBC was positively and significantly correlated with pH ($r=0.800^{**}$), EC ($r= 0.875^{**}$) and CEC ($r=0.896^{**}$). The TC was positively and significantly correlated with pH ($r=0.782^{**}$), EC ($r= 0.851^{**}$) and CEC ($r=0.863^{**}$).

Chapter-5

Discussion

DISCUSSION

The results obtained with respect to different parameters “Spatial variability of soil nutrients and carbon pools under different land uses in hilly zone of Doda District of J&K” have been discussed in the following headings:

5.1 Physico-chemical properties of soils

5.2 Soil exchangeable cations

5.3 Soil available nutrients

5.4 Soil organic carbon pools

5.5 Relationship between soil properties and soil nutrients

5.6 Relationship between soil properties and SOC pools

5.1 Physico-chemical properties of soils

The highest bulk density under surface soil (0-20 cm) was observed in eroded land use system followed by barren land use, grassland land use, agriculture land use, horticulture land use and forest land use. The high bulk density of soil in eroded Land use may be attributed low clay content as well as low organic carbon and high sand . This might be compaction of finer particles of clay and fewer content of organic carbon with increasing depth under different land use systems. (Reddy and Naidu, 2016) also reported an increasing in bulk density with depth under different pedons in semi-arid region of Chennur, Mandal of Andhra Pradesh. Bulk density increased with depth in all the land use systems. The increasing bulk density with depth under all land use system can be due low organic carbon, clay and reduced aggregation. Similar trend in bulk density with depth has also been observed by different workers under different soil types, Aumtong *et al.*, 2009; Barreto *et al.*, 2010; (Singh *et al.*, 2012, Karmakar 2014b). However, Debasish-shah *et al.*, (2011) reported the lowest bulk density in Eroded Land use soil because of loose deposited material especially in 0-20 and 20-40 cm soil layers. Normally the bulk density in Eroded Land use soils has to be higher due to the removal of finer particles, soil organic carbon and impact of falling raindrops. Swarnam *et al.*, (2004) reported that the increase in bulk density with depth was attributed to lower organic matter, more compaction and less aggregation in soil.

The lower bulk density in surface soil may be due cultivation of crops, high organic matter content and biotic activities.

The water holding capacity values were observed to be highest in forest land use system followed by eroded, forest, grassland, horticulture, agriculture, barren land and eroded land use. The value of WHC with depth decreased under all land use systems. The difference in the water holding capacity under different land uses might be due to the variation in clay and organic carbon content and heterogeneity of parent material. Similar results were also reported by Sathyavathi and Reddy (2004) in soils of Sivagiri micro-watershed in Chittoor district of Telangana region of Andhra Pradesh. Goyal (2009) also observed similar trend in porosity and water holding capacity under forest, grassland land use and agriculture land use. The highest values of water holding capacity in forest land use system. It could be attributed to high soil organic matter and finer clay content in these soils. The decreasing trend of WHC with depth may be due to less organic carbon and clay content of soil under different land use systems. These findings corroborate the result reported by (Reddy and Naidu, 2016) and Dutta *et. al.*, 2017.

The sand content of surface soil (0-20cm) was observed highest in eroded land use followed by forest land use, barren land use system, horticulture land use, grassland land use, agriculture land use and forest land use systems. However, no consistent trend with respect to sand content at different depth was recorded among all land use systems. The high value of sand in eroded land use may be large content of sand bearing minerals and fragile nature of soil as well as low level of clay, organic matter and can be attributed in situ weathering of parent material whereas, higher level of sand under different land use system might be high organic carbon and less amount of clay content. High content of sand in eroded land uses may be the richness of parent material along with its fraction whereas least sand content was observed in forest land use system might be high organic matter through leaf litter fall and high content of clay in soil. These finding are in line with those reported by Singh *et. al.*, 2012; Rehman *et. al.*, 2017 and Dutta *et. al.*, 2107.

The silt content of surface soil (0-20cm) was found highest in eroded land use followed by agriculture land use, eroded land use system, barren land use system, forest land use system, horticulture land use system and grassland land use system and agriculture land use system. However, no consistent trend with respect to silt content

at different depth was recorded under different land use systems. It may be high weathering intensity under different land use systems. These finding are in line with those reported by Singh *et. al.*, 2012 and Rehman *et. al.*, 2017).

The clay content of surface soil (0-20cm) was observed highest in forest land use followed by eroded land use, forest land use system, grassland use system, horticulture use system, agriculture land use system, barren land use system and eroded land use system. However, no consistent trend with respect to clay at all depth was recorded under different land use system. The higher clay content in the lowest depth can be attributed to the process of illuviation, rather than stratification of parent material. These results in line with those reported by Gupta and Tripathi (1992; Gupta and Verma, 1992 and Dutta *et. at.*, 2017).

The pH content of surface soil (0-20cm) was observed highest in eroded land use followed by barren land use system, agriculture land use system, grassland land use system, horticulture land use system and forest land use system. The increases with increasing depth in all land use systems. The increase in pH with depth could be due to leaching of calcium carbonate and exchangeable bases. The soil pH variability is usually attributed to organic materials in the soil which produce organic acids on their decomposition including carbonic acid which eventually lowers down the soil pH. Sarkar *et al.* (2001) also reported that the low pH value in surface soil is mainly due to leaching of bases and accumulation of basic cations from higher topography due to rainfall (Garcha, 2016 and Dutta *et. at.*, 2017). Similar finding had been observed by Sharma *et al.* (2009), in *kandi* soils of Jammu. The soils under study varied from slightly acidic to neutral in nature.

The EC content of surface soil (0-20cm) was found highest in horticulture land use followed by horticulture land use system, agricultures land use system, barren land use system, forest land use system, grassland land use system and eroded land use system. However, no consistent trend with respect to EC at all depth was recorded under different land use system which is possibly due to the slow mobility of salts of various ions (Cl^- , SO_4^{2-} , HCO_3^- , CO_3^{2-} , Na^+ , Ca^{2+} , Mg^{2+} , and K^+) towards lower horizons or low concentration of soluble salts because of rapid water movement through soil profile (Sondhi, 1992 and Nazir, 1993). The high EC value in the surface layer compared to sub-surface layers could also be due to upward movement of soluble salts to the surface through capillary rise of water under prevailing 'hyper-

thermic' temperature regime in submontane soil (Sondhi, 1992). Moreover, all the EC values found in all land use systems are in normal range.. Similar findings were reported by (Phuntsing *et. al.* 2015; Singh *et. al.*, 2012, Garcha, 2016).

The CEC value of surface soil (0-20cm) was observed highest in forest land use followed by forest land use system, grassland land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The CEC content decreased with depth in all land use systems. The low CEC in eroded land use low organic carbon, low clay and high value of sand in these soils. Forest Land use system had the highest clay content which is the reason for high CEC in forest land use soils and also high OC in forest land use reflect to the presence of high organic matter in these soils which is another reason for higher CEC values in Forest Land use soils. These observations are in conformity with those reported by Gupta and Khanna, 1994; Karmakar, 2014(b) and Dutta *et. al.*, 2017.

The CaCO_3 of surface soil (0-20cm) was observed highest in barren land use followed by grassland land use system, horticulture land use system, agricultures land use system, eroded land use system and forest land use system. The CaCO_3 value increased with depth in all land use systems. The increasing trend of CaCO_3 with depth could be leaching of calcium and its subsequent precipitation in lower horizons. The CaCO_3 decreased in eroded land use of compared to soils with good vegetative cover may be due to removal of surface soil which increased with the depth in all land use systems. Lowest CaCO_3 value in forest soils as compared to other land uses might be lower pH and presence of organic acids due to composition of organic matter, it can be increasing pH of soil and accumulation of basis with depth under barren land use system. Similar findings were observed by Reddy and Naidu, 2016. However, the increase with soil depth was more apparent in barren soils.

The *exch. Ca* value of surface soil (0-20cm) was found to be highest in barren land use followed by grassland use system, horticulture land use system, agriculture land use system, forest land use system and eroded land use system. However, no consistent trend was recovered with respect to *exch. Ca* at different depth was recorded under different land use system. The higher value of Ca in barren land use system may be due to dominance of calcification process whereas low values of Ca under different land use system could be ascribed because of low level of Ca due to crop removal as well as and leaching of Ca during high intensity of rainfall, Gebrelibonos and Assen

(2013) also observed similar finding while studying the effect of different land use systems on Ca. These observations are supported by Maqbool *et. al.* 2017 and Dutta *et. al.*, 2017.

5.2 Soil exchangeable Cations

The exch. Mg value in surface soil (0-20cm) was observed to be highest in barren land use and lowest in eroded land use and followed by trend: barren land use system, grassland use system, horticulture land use system, agriculture land use system, forest land use system and eroded land use system. However, no consistent trend with respect to Mg at different depth was recorded under all land use systems. The higher value of exch. Mg could be in barren land due to dominance of magnesium containing minerals while low value of exch. Mg in eroded land use system might be scanty vegetation and its fragile nature as well as poor fertility and leaching of exch. Mg during high intensity rainfall. These observations are in line with those reported by Maqbool *et. al.* 2017. and Dutta *et. al.*, 2017.

The exch. Na value of surface soil (0-20cm) was found highest in forest land use system and lowest in eroded land use system and followed by pattern: forest land use system, grassland use system, agriculture land use system, horticulture land use system, barren land use system and eroded land use system. The exch. Na decreases with depth under all land use systems. The highest exch. Na in Forest land use may be due to redistribution of the Na by tree species whereas lowest exch. Na in eroded land use can be scanty vegetation and fragile nature of soil. These findings are corroborated with the results reported by (Patel and Jagdish Prashad, 2004 and Dutta *et. al.*, 2017).

5.3 Soil Available Nutrients

The available N value of surface soil (0-20cm) was highest in forest land use and lowest in eroded land use system and followed in trend: forest land use system, grassland land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The mean value of available N was low to medium in surface soils among all land use systems. The mean value of available N decreases with depth under different land use systems. It may be low crop intensity, decreasing trend of organic matter with depth resulting less mineralization rate owing to low temperatures during most part of the year. The higher value of available N under forest land use system might be larger leaf litter falls and rapid

decompositions of organic matter responsible for enhanced N whereas less value of N under eroded land use system could be due to high erosion and growing less vegetation. These findings are in conformity with those reported by Singh *et. al.*, 2012; Garcha, 2016 and Maqbool *et.al.*, 2017.

The available P of surface soil (0-20cm) was found highest in forest land use and lowest in eroded land use system and followed by pattern: forest land use system, grassland land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The available P values decrease with depth under different land use systems. The mean value of available Phosphorus was low to medium range in surface soils (0-20cm) among all land use systems. The high content of P under forest land use system followed by grassland use system might be due to more storage of organic matter which releases organic anions on decomposition and form chelates with Fe and Al and ultimately releases available P whereas low content of P under eroded land use system could be due to least vegetation and no addition of P through organic and inorganic sources. These observations are similar with the findings of Najar *et. al.* 2002; Singh *et. al.*, 2012; Garcha, 2016 and Maqbool *et.al.*, 2017.

The available K content of surface soil (0-20cm) was observed highest in forest land use and lowest in eroded land use and followed in order: forest land use system, grassland use system, agriculture land use system, horticulture land use system, barren land use system and eroded land use system. The available K values decrease with depth under different land use systems. The mean value of available K was in medium range in surface soil (0-20cm) among all land use system. The high value of available K under forest land use system could be due to more leaf litter falls from trees and added substantial amount of K after decomposition in the soil whereas low content of K under eroded land use system due to fewer vegetation and its fragile nature. These observations are in line with those reported by Singh *et. al.* (2012).. Gandhi (2015) also reported higher value of available K in forest soils as compared to other land use system. These results are in conformity with those reported by Kiflu and Beyene 2013; Singh *et. al.*, 2012; Garcha, 2016 and Maqbool *et.al.*, 2017.

The higher value of available S in surface soil (0-20 cm) was observed in forest land use system and lowest in eroded land use system and followed by pattern: forest land use system, grassland use system, horticulture land use system, agriculture land

use system, barren land use system and eroded land use system. The higher mean value of available S under forest land use system can be more addition of leaf litter falls which produces organic acids resulted enhanced sulphur in the upper strata of forest land use system whereas fewer amount of available S under eroded land use system may be attributed loss of fertile soil from upper surface and low vegetation. These results are in line with those reported by Farida *et al.*, (2008) and Maqbool *et al.*, (2017).

5.4 Available Micro-Nutrients:

The available Fe in surface soil (0-20cm) was found highest in forest land use and lowest in eroded land use and followed by trend: forest land use system, grassland use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The available in Fe decreases with depth under different land use systems. The available Fe value was sufficient in majority of under all land use systems. This may be attributed sufficient organic matter in surface soils under major land use systems responsible for high micronutrient availability because of chelating action of organic compounds released during decomposition of organic manures and prevention of cations from fixation, precipitation, oxidation and leaching. These results are similar with the findings of Nazif *et al.*, (2006), Babu *et al.*, (2007) and Kirmani *et al.*, (2011). The low content of available Fe in eroded land use system may be fewer vegetations and removal of surface soil which derived from fragile parent material. These results are in line with those reported by Singh *et al.*, 2012 and Katkar 2017.

The available Cu of surface soil (0-20cm) was observed highest in forest land use and lowest in eroded land use and followed in order: forest land use system, grassland land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The available Cu values decreases with depth under all land use systems. The higher content of available Cu in forest land use system might be more addition of leaf litter fall which releases sufficient amount of Cu after decomposition and mineralisation while low amount of available Cu in eroded land use system may be least of vegetation which results in scanty mineralization. These results are in conformity with the studies of Chattopadhyay *et al.*, (1996). The soils with good organic matter content have high micronutrient availability due to chelating action of organic compounds released during

decomposition and prevention of cations from fixation, precipitation, oxidation and leaching (Babu et al., 2007 and Singh *et. al.*, 2012).

The available Zn content of surface soil (0-20cm) was found highest in forest land use and lowest in eroded land use and followed in trend: forest land use system, grassland land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The available Zn values decreases with depth under different land use systems. The DTPA- extractable zinc was higher in surface soil in consideration of critical limit (0.6 mg /kg) which may be high organic matter content and more weathered soil conditions. The higher value of available Zn in forest land use system might be due to high organic carbon and clay content in soils whereas least value of available Zn in eroded could be low organic matter and of clay in soil. These results supported by the findings of Chattopadhyay *et al.*, (1996). Who also found sufficient values of zinc in the hilly soils. Available Zinc was almost sufficient under majority of land uses and deficient in very limited area because zinc may be precipitated as hydroxides and carbonates under eroded and barren soils. Nazif *et. al.* (2006) also reported that micronutrient availability enhanced in soils with organic matter over no organic manure.

The available Mn content of surface soil (0-20cm) was found to be highest in forest land use and lowest in eroded land use and followed by pattern: forest land use system, grassland land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The available Mn values decreases with depth under different land use systems. The Available Mn was sufficient range in majority of land use systems. The higher value of available Mn in forest land use system might be more availability of organic matter in soil through leaf litter fall whereas least value of available Mn in eroded land use system may be very low organic matter in soil and poor physico-chemical and biological properties of soils. Sufficient content of manganese was also observed in hilly terrains by Yeresheemi et al. (1997) due to high organic matter content in soils. Available manganese (Mn) considering 1.0 mg kg⁻¹ as the critical limit (Lindsay and Norvell 1978), cent percent of the soils were sufficient in available Mn. soils with good organic matter content have high micronutrient availability due to chelating action of organic compounds released during decomposition of these manures and prevention of

cations from fixation, precipitation, oxidation and leaching (Babu et al., 2007). These findings are corroborates the observation of Katkar *et. al.* (2017).

5.5 Soil organic Pools

The SOC content of surface soil (0-20cm) was found highest in forest land use and lowest in eroded land use and followed by trend: forest land use system, grassland use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The SOC values decreases with depth under different land use systems. The soil organic carbon in the soils of all land use system was usually high because most of the area of hilly terrains is least cultivated and covered with Forest Land use type of vegetation. The higher value of SOC in forest land use system might be due to addition of organic matter in the form of leaf litter fall which is subjected to microbial decomposition and intensity of composition is a function of soil moisture, temperature and kind of organic input. whereas least value of SOC in eroded land use system less availability of organic carbon and poor physico-chemical and biological properties in soil. These findings are in conformity with those reported by Mishra *et. al.* (2004) Wang *et. al.* (2010) and Garcha *et. al.*, 2016.

The water soluble carbons content of surface soil (0-20cm) was found highest in forest land use and lowest in eroded land use and followed in order: forest land use system, grassland land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The water soluble carbon values decreases with depth under all land use systems. The decreasing values of water soluble carbon in all land use system might be linked with declining trend of organic carbon content as well as compactness of sub soils Lokaria *et. al.* 2012 while studying of water soluble carbon under different land use system of central India observed similar results also.

The LC value of surface soil (0-20cm) was observed highest in forest land use and lowest in eroded land use and followed by pattern: forest land use system, grassland use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The LC values decreases with depth under different land use systems. The higher LC in forest land use soils may be ascribed to continuous addition of leaf litter fall and decomposition of organic matter

which releases higher labile carbon as compared to other land uses. Increasingly LC under forest land use system might be due to its oxidation derives the flux of carbon dioxide from soil to atmosphere as well as labile carbon is one which is readily decomposable, easily oxidisable and susceptible to microbial attack and is sensitive to management induced changes in soil organic carbon. Moreover, labile carbon is important as it fuels the soil's food web and greatly influences the nutrient cycling for minting the quality of soil and its productivity. These findings are in conformity with those reported by Majumder (2006), Verma *et al.* (2010) and Lakaria (2012). However, low content of LC under eroded land use system can be due to ruptured physico-chemical and biological properties of soils and least decomposition of organic matter. Similar finding are reported by Mishra *et al.* (2002).

The MBC of surface soil (0-20cm) was highest in forest land use and lowest in eroded land use and followed by trend: forest land use system, grassland land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The MBC values decreases with depth under different land use systems. The microbial biomass C was higher in forest land use tree-based systems as compared to mono cropping. The high content of MBC under forest land use system could be higher quantity of SOC which provide sufficient organic carbon for proliferation of micro-organisms. Moreover, a general microbial biomass carbon showed in improvement in most of the land use systems whereas eroded land use systems and barren land use system exhibited lower value of MBC. These observations corroborate the finding of Lakaria *et al.*, (2012). A significant decline of MBC with soil depth has also been reported by different workers Shrestha *et al.*, (2007) and Huang and Song, (2010).

The TC content of surface soil (0-20cm) was found highest in forest land use and lowest in eroded land use and followed in order: forest land use system, grassland land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system. The TC values decreases with depth under all land use systems. The higher values of TC under forest land use system, grassland use system, horticulture land use system could be higher organic carbon addition in the form of leaf litter falls, residue in corporation or application of organic material. However, less value of TC under eroded land use system may be ascribed to least amount of organic carbon content and disturbed physio-chemical and geological

properties of soils. Similar findings were reported by Mishra *et. al.* (2004) and Lakaria *et.al* (2012) .

5.6 Relationship between soil properties and available nutrients in Agriculture land use system (0-100 cm)

The relationship between N and pH, sand and clay were positively significant might be due to neutral pH of soil and moderate clay content of soil. Whereas negative correlation with silt, Exch. Ca, EC, CEC, CaCO_3 , and Exch. Mg, was observed. This may be high status of concerned soil properties. The available P was positively and significantly correlated with pH, sand, CaCO_3 , clay and exch. Mg might be due to neutral nature of soil with moderate content of organic carbon, negatively correlated with BD, WHC, clay and silt may be higher status of concerned soil properties. The available K was significantly correlated with clay, pH, CEC and sand could be due to richness of soil in K bearing minerals whereas negative relationship with BD, silt, EC, exch. Ca, and Mg might be due to enhanced value of concerned properties, the positive relationship of available S with sand, clay, EC, CEC may be attributed due to moderate content of organic carbon, however, negatively correlated with WHC, sand, silt, CEC, exch. Ca and Mg might be less content of S and increased concerned soil properties. The available Fe content was positively and significantly correlated with sand, clay, exch. Na, silt, EC, may be due to neutral nature of soil and high content of Fe bearing minerals whereas negatively correlated with CEC, exch. Ca, BD, exch. Mg but the value of sand was negative and significantly correlated with Fe, might be high quantity of concerned soil properties. The positive relation of Cu with silt, clay, Na, EC can be ascribed due to moderate content of organic carbon which releases sufficient amount of Cu in soil whereas negatively correlated with sand, silt, EC, exch. Ca, exch. Mg exch. and BD, this may be due to higher values of physico-chemical properties of soil. The positive significant relationship between Zn and Ca, clay, EC may be due to high content of Zn released due to decomposition of organic carbon whereas negative correlation with BD, WHC, silt, pH, EC, exch. Mg, exch. Na, CaCO_3 was observed. It may be low content of Zn and enhance concerned soil properties. The positively significant relationship between Mn with pH, Na, EC was observed, it may be due to high neutral pH of soil whereas negative relationship with BD, sand, CEC, exch. Ca, exch. Mg, CaCO_3 , WHC, silt, clay, pH, EC were observed may be increased soil related properties. However negatively significant with exch. Na, exch. Ca were

noticed at 0-20, 40-60 depth respectively. These observations are supported by the findings of Kozak *et. al.* (2005); Sharma *et. al.*, 2013; Singh *et. al.*, 2016 and Maqbool *et. al.*, 2017.

5.7 Relationship between soil properties and available nutrients in Horticulture land use system (0-100 cm)

The N was positively and significantly correlated with silt, this may be due to neutral pH of soil. However, negatively correlated with sand, pH, *exch. Ca*, EC and clay, it may be due to higher status of concerned soil properties. The available P was positively and significantly correlated with CaCO_3 and *exch. Na*, this may be due to neutral nature of soil and moderate content of organic carbon, whereas negatively correlated with sand, clay, EC, *exch. Ca*, BD, may be higher physico-chemical properties of soil. The relationship between K with CaCO_3 was positively and significantly correlated this may be due to richness of soil in available K bearing minerals and negatively correlated with sand, pH, EC, silt, might be due to higher status of concerned properties. The relationship between available S with clay and pH was positively and significantly correlated, this may be attributed moderate content of organic carbon. However, negatively correlated with BD, sand, EC, CEC, CaCO_3 and *exch. Na*. This may be due to high values of concerned soil properties. The available Fe was positively and significantly correlated with CaCO_3 and clay, this may be high content of Fe bearing minerals and negatively correlated with sand, pH, EC, *exch. Ca*, this may be higher status of concerned soil properties. The relationship between Cu was positively and significantly correlated with CEC and *exch. Na*, it may be moderate content of organic carbon which releases sufficient amount of Cu in soil whereas negatively correlated with BD, WHC, *exch. Ca*, sand, pH, silt, *exch. Mg*, EC and clay, might be increasing soil physico-chemical properties. The available Zn was positively correlated with WHC, sand, *exch. Mg*, pH, *exch. Na*, this may be due to high content of Zn released due to decomposition of organic carbon and negatively correlated with BD, clay, EC, CaCO_3 , CEC, silt, sand, *exch. Ca*, could be ascribed due to higher physical and chemical properties of soil. The relationship between Mn was positively correlated with WHC, sand, silt, EC, CEC, CaCO_3 , *exch. Ca* and *exch. Na*, could be neutral pH of soil, whereas negatively correlated with BD, silt, clay, *exch. Ca*, this may be due to high values of physical chemical properties of soil. These findings corroborate the result reported by Maji *et. al.*, 1993 and Maqbool *et. at.* 2017.

5.8 Relationship between soil properties and available nutrients in Forest land use system (0-100 cm)

The available N was positively and significantly correlated with pH, CaCO_3 , this may be neutral pH of soil and moderate clay content of soil and negatively correlated with silt, BD, exch. Ca, WHC, sand, exch. Na, this may be due to higher values of physical and chemical properties of soil. The relationship between P with pH, CaCO_3 and CEC was positive significant, it may be neutral nature of soil and moderate content of organic carbon whereas negatively correlated with sand, silt, EC, exch. Ca and exch. Mg, this may be due to higher status of concerned soil properties. The relationship between available K was positively and significantly correlated with clay which may be due to richness of soil in K bearing minerals, however negatively correlated with sand, exch. Ca, exch. Mg, EC, sand, this may be higher value of soil properties. The relation between available S with BD and CaCO_3 was positively significantly, this may be attributed to high content of organic carbon however negatively correlated with clay, EC, exch. Ca, sand, silt and exch. Mg, may be due to high values of concerned soil properties. The available Fe was positively and significantly correlated with pH and CaCO_3 . This may be high content of Fe bearing minerals, negatively correlated with sand, silt, EC, exch. Ca and BD might be due to higher status of concerned soil properties. The relationship between Cu was positively and significantly correlated with Exch. Mg and CaCO_3 was positively significant, this may be higher content of organic carbon which released sufficient amount of Cu in soil, it was negatively correlated with Exch. Ca, sand, pH, silt, EC, clay this may be increased concerned soil physico-chemical properties. The available Mn was positively correlated with CEC, CaCO_3 and pH and clay. This can be due to high content of Mn released due to decomposition of organic carbon and negatively correlated with BD, EC, silt and exch. Ca, it could be higher physical and chemical properties of concerned soil. The relationship between Zn was positively correlated with clay, pH, Ex. Mg WHC, silt, CEC, CaCO_3 , and exch. Na may be neutral pH of soil, whereas negatively relationship with sand, BD, EC and exch. Ca, was observed, this may be due to high values of physical chemical properties of soil. These observations are supported by Katkar *et. al.* (2017) and Maqbool *et. at.* 2017.

5.9 Relationship between soil properties and available nutrients in grass land use system (0-100 cm)

The available N was positively and significantly correlated with EC, silt, CEC, pH and CaCO_3 , this may be neutral pH of soil and higher organic carbon and clay content of soil and negatively correlated with BD, *exch. Ca*, WHC, clay, sand, *exch. Ca* and *exch. Mg*, this may be due to higher values of physical and chemical properties of soil and negatively correlated with clay at 0-40 cm depth. The relationship between P and silt, clay and *exch. Mg* was positive, it may be neutral nature of soil and high content of organic carbon and negatively significant with pH, BD, WHC, sand, CEC, EC and *exch. Ca* it could be due to high status of concerned soil properties. The relationship between available K and pH and CaCO_3 was positively significant, it may be due to richness of soil in K bearing minerals, however negatively correlated with WHC, clay, silt and BD, this may be higher value of related soil properties. The relation between available S with pH, EC, sand, CEC and CaCO_3 was positively significant, this may be attributed due to high content of organic carbon however, it was negatively correlated with BD, *exch. Mg*, and *exch. Ca*, it could be high values of concerned soil properties, barring negatively correlated with clay. The available Fe was positively and significantly correlated with silt, EC, pH, CEC, and CaCO_3 . This may be due to high content of Fe bearing minerals however, it was negatively correlated with BD, WHC, *exch. Ca* and *Mg* and clay, it may be higher status of concerned soil properties. The relationship between Cu with CaCO_3 was found to be positive correlated. This may be higher content of organic carbon which released sufficient amount of Cu in soil whereas negatively correlated with BD, clay *Exch. Ca*, *exch. Mg* and *exch. Na*, this may be due to increased soil physico-chemical properties. The relationship between Zn with BD, sand, EC, pH, *ex. Mg*, WHC, CaCO_3 , and *exch. Ca* was positively correlated, it may be due to neutral pH of soil, whereas negatively relationship with silt, clay and *exch. Na* was found, this may be high range of physical chemical properties of soil. The available Mn was positively correlated with BD, WHC, sand CEC, *exch. Mg*, *exch. Na*, EC and CaCO_3 . This may be due to high content of Mn released due to decomposition of organic carbon and negatively correlated with silt, clay, pH and *exch. Ca*, might be due to higher physical and chemical properties of concerned soil. Similar results were observed by Yihenew *et. al.*, 2015 and Maqbool *et. at.* 2017

5.10 Relationship between soil properties and soil organic carbon pools in Agriculture land use system (0-100 cm)

The relationship of SOC with EC, CEC, CaCO_3 was positively significantly, it could be richness of soil in organic carbon which results faster mineralization in soil, whereas negatively correlated with BD, WHC, silt, clay, pH, *exch. Na*, sand and EC, it may be enhanced concerned soil properties. The relationship between WSC with CEC, CaCO_3 , silt was found positively significant, may be due to enhanced decomposition of organic carbon responsible for releasing WSC in soil, negatively correlated with WSC, sand, silt, EC, *exch. Ca*, BD, pH, *exch. Mg* and *exch. Na*, may be higher values of soil properties. However, clay content was negatively significant with WSC at (60-100 cm) depth may be due to less content of organic carbon and enhanced value of clay. The LC was positively significant with silt, clay, EC, pH, could be due to its high level after decomposition of organic matter in soil, negative correlation of LC with silt, sand, CaCO_3 , may be high values of related soil properties. Barring, the relationship of LC with sand was negatively significant at 0-20 and 20-40 cm depth. The EC was negatively significant may be enhanced concerned soil properties. The value of MBC was positively and significantly correlated with CaCO_3 may be more activities of microbial counts due to greater availability of OC and negatively correlated with WSC, sand, silt, pH, EC, BD, clay, might be increased concerned soil properties. However, the value of sand and silt were negatively significant at 40-60 and 60-100 cm depth respectively. The relationship of TC with CEC, CaCO_3 , pH was positively significant, may be due to moderate content of OC. However, negative relationship with BD, WSC, clay, *exch. Na*, EC, sand, *exch. Mg* and pH was observed. It could be increasing values of concerned soil properties. These findings corroborate the result reported by Blair *et al.*, 1995, Verma *et al.*, 2010, Lakaria *et al.* 2012 and Dutta *et al.*, 2015.

5.11 Relationship between soil properties and soil organic carbon pools in Forest land use system (0-100 cm)

The relationship between SOC with *exch. Na*, pH and sand was positively and significantly correlated, may be greater decomposition of organic matter accumulated slowly in longer period through leaf litter fall in forest soils where as negatively correlated with BD, clay, *exch. Ca*, WSC, silt were observed, may be due to enhanced

these soil properties. except with clay at 40-60 and 60-100 cm depth respectively. It might be due to high content of clay in forest soil. The relationship between WSC with silt, EC, CEC, CaCO_3 , pH, exch. Na was positively and significantly. It may be due to highly solubling nature, which enhances its content. However, negatively correlated with WHC, exch. Ca , exch. Mg , clay, BD and silt can be higher values of concerned soil properties, barring clay at 0-20 depth found negatively significant. The relationship between LC with EC, CEC, CaCO_3 , pH was positively and significantly correlated transfer of greater LC from solid phase to soluble form, negatively correlated with BD, clay, exch. Ca and exch. Mg were observed enhanced concerned soil properties except negatively correlated with clay in 0-20 cm depth. The relationship between MBC with EC, CEC, CaCO_3 , pH was observed positively significant, might be greater prolific growth of microbial counts more availability of organic carbon under forest soils and negatively correlated with BD, exch. Mg and exch. Ca , clay and WSC due to higher values of physico-chemical properties of soil. The positively significant correlation of TC with CaCO_3 , silt, pH was observed higher accumulation of leaf litter which releases sufficient amount of organic carbon and solubilised native form of inorganic carbon and it was negatively correlated with BD, exch. Mg , exch. Ca , clay, WHC might be increasing values of concerned soil properties barring negatively significant with clay at 0-20 cm depth. These results corroborate with the findings reported by Mishra *et. al.*, 2014, Mujamdar *et. al.* 2006, Lakaria *et. al.* 2012 and Dutta *et al.*, 2015.

5.12 Relationship between soil properties and soil organic carbon pools in Horticulture land use system (0-100 cm)

The relationship between SOC with clay, pH, CaCO_3 and sand was positively significant, may be high decomposition of organic matter accumulated slowly in longer period through leaf litter fall in Horticulture soils where as negatively correlated with BD, EC, CEC, exch. Ca , sand, exch. Na , may be enhanced concerned soil properties whereas SOC was negatively correlated with sand and exch. Ca at 0-20 and 20-40 cm depth, might be high level of clay in horticulture soil. The relationship between WSC with CaCO_3 , was positively significant. It may be its highly solubling nature which enhances its content. However, negatively correlated with sand, pH, EC, silt, exch. Ca and sand due to higher values of concerned soil properties. The relationship between LC with CaCO_3 , clay was positively significant, greater movement of LC from solid phase to soluble form, negatively correlated with sand,

pH, EC, silt, *exch. Ca* were observed due to enhanced concerned soil properties except negatively significant with clay was observed in 0-20 cm depth. The relationship between MBC with EC, clay, CEC, CaCO_3 was observed positively significant, might be due to higher prolific growth of microbial counts and greater availability of organic carbon in soils and negatively correlated with sand, pH, EC, BD, *Exch. Mg* and *Ca*, clay, silt due to higher values of physico-chemical properties of soil. The positively significant correlation of TC with CaCO_3 , silt was recorded due to higher accumulation of leaf litter falls which releases high amount of organic carbon and solubilised native form of inorganic carbon and negatively correlated with BD, *exch. Mg*, *Ca*, clay, WHC, might be due to increasing values of concerned soil properties however, it was negatively significantly with sand at 0-20 cm depth. Similar results were reported by Kundu *et al.* 2001, Lakaria *et al.* 2012 and Dutta *et al.*, 2015.

5.13 Relationship between soil properties and soil organic carbon pools in grassland use system (0-100 cm)

The relationship between SOC with *exch. Mg*, clay, pH and CaCO_3 and sand was positively significant. It may be high decomposition of organic matter accumulated slowly in longer period through leaf litter fall in grassland soils where as negatively correlated with silt, EC, *exch. Ca*, sand, BD, may be enhanced soil properties. However negatively significant with sand and *exch. Ca* at 0-20 and 20-40 cm depth might be due to high content of clay in grassland soil. The relationship between WSC with CaCO_3 , *exch. Na*, pH was positively significant. It can be highly solubilising nature which enhances its content. However, negatively correlated with sand, EC, silt, *exch. Mg*, sand, BD due to higher values of concerned soil properties. The relationship between LC with pH, CaCO_3 , CEC was positively and significantly correlated, it may be due to greater movement of LC from solid phase to soluble form, negatively correlated with sand, pH, EC, silt, *exch. Ca* due to enhanced concerned soil properties however negatively significant with clay was observed in 0-20 cm depth. The relationship between MBC with EC, clay, CEC, CaCO_3 was observed positively significant can be greater prolific growth of microbial counts and more availability of organic carbon in soils whereas, negatively correlated with silt, EC, *exch. Ca*, EC, BD, sand, clay, silt was observed due to higher values of physico-chemical properties of soil. The positively significant relationship of TC with pH, CEC, CaCO_3 may be higher accumulation of leaf litter falls which releases high amount of organic carbon

as well as solubilised native form of inorganic carbon and negatively correlated with silt, EC, BD, *exch. Ca*, *exch. Mg* might be due to increasing values of concerned soil properties. Similar results were reported by Mishra *et al.* 2002; Lakaria *et al.* 2012; Dutta *et al.*, 2015 and Srinivas *et al.*, 2015.

Chapter-6

Summary and Conclusion

SUMMARY AND CONCLUSION

Spatial variability of soil properties is having paramount importance in hill agriculture. Soil properties vary spatially from field to a large region scale and one influence by geology, topography, climate as well as land use and management strategy. Soil organic carbon preservation in different land use system is critical to maintenance of soil fertility, productivity and reduction of CO₂ losses in the atmosphere. The use of soil management practices enhances soil carbon sequestration and its distribution in the soil profile to mitigate the green house effect. There is scanty information available on soil nutrients under temperate hilly zone of Jammu region. Therefore the study on spatial variability of soil nutrient and carbon pools under different land uses in temperate hilly zones of Doda district (J&K) was under taken and summarized with the following objectives

- To assess the physico-chemical properties of soil under different land uses.
- To monitor the spatial variability in soil nutrients under different land uses.
- To evaluate the carbon pools in soil under different land uses.+
- To establish relationship between carbon pool and available nutrients /soil properties.

Physico-chemical properties of soils

The pH of the soils of hilly areas was slightly acidic to neutral/ near neutral in nature. The lowest value pH was recorded in the surface soils (0-20 cm) of forest land and highest in eroded land. The pH generally increased with depth in all land use systems. The concentrations of soluble salts were in safe range and the texture of the soils of majority of the land uses was sandy loam to sandy clay loam. The mean value of sand in the surface soil was highest in eroded landuse and lowest in forest landuse system, however, mean value of silt in surface soil was highest in eroded land and lowest in agriculture land. The clay content was highest in forest land use system and lowest in eroded landuse system.

The results showed that the mean bulk density of the surface soil was highest in eroded lands followed by barren land, grassland, agriculture, horticulture and was

lowest in forest lands. Bulk density increased with soil depth in all the land use systems. The water holding capacity was highest in forest land followed by grassland, horticulture, agriculture, barren and lowest in eroded soils. Maximum water holding capacity decreased with depths in all land use systems.

The results showed that the lowest mean value of CEC was observed in eroded soil and highest in forest soil. CEC was decreased with depths in all land use system. The lowest mean value of CaCO_3 was observed in eroded and highest mean value of CaCO_3 was found in forest soils. The CaCO_3 was increased with depths in all land use system. The lowest mean value of exchangeable Ca was observed in eroded soil and highest in forest soils. The Ca was decreased with depths in all land use systems. The lowest mean value of exchangeable Mg was observed in eroded and highest mean value of Mg was found in forest soils. The Mg was decreased with depths in all land use systems. The lowest mean value of exchangeable Na was observed in eroded soils and highest in forest soils.

Available macro nutrients

The mean value of available nitrogen in the surface soil was found to be highest in forest soils, lowest in eroded lands. The surface soil of eroded land was found low (< 272 kg/ha) in available nitrogen content. Whereas grass, forest, horticulture and barren were observed medium to low. The mean value of available phosphorus of the surface soil was low (< 10 kg/ha) in eroded lands whereas in forest, grass horticulture, agriculture and barren soils were high to medium (10-25 kg/ha). The mean value of available potassium of surface soil was highest in forest soils and lowest in eroded soils and followed by trend forest, grassland, agriculture, horticulture and eroded soils pertaining medium to low range. The value of available N, P and K were decreased with the increase in soil depth for all land use systems. The mean value of available sulphur of surface soil was found to be highest in forest and lowest in eroded lands. The available S in other land uses was observed in low to medium range and decreased with depth under all land use systems.

Available Micro Nutrients

The mean value of available Fe in the surface soil was found highest in forest soils and lowest in eroded soils. The available Fe in surface soil under study was highest in the majority of land uses including grass, horticulture and agriculture. The

mean value of available Cu in the surface soil was found to be highest in forest soil and lowest in eroded soils. The available Cu in surface soil among all land uses was higher to medium in range. The mean value of available Zn in the surface soil was found to be the highest in forest soil and lowest in eroded soils. The available Zn in surface soil was in medium range. The mean value of available Mn in the surface soil was found in sufficient range in forest soil and lowest in eroded soils. The available Mn in surface soil was found moderate in almost all land use system.

Soil organic carbon pools

The soil organic carbon in surface soil (0-20 cm) was highest in forest land and followed by grassland, horticulture, agriculture, barren, and eroded lands. The forest and grasslands registered highest organic carbon respectively. The high value of soil organic carbon in surface soil under all land use systems viz., forest, grassland, horticulture, agriculture was observed whereas in barren land the percentage was medium and lowest in eroded land. The hot water soluble carbon content in the surface soil (0-20 cm) was highest in forest followed by grassland, horticulture, agriculture, barren and lowest in eroded lands. The decrease of WSC with soil depth was pronounced. The LC in the surface soil (0-20 cm) was highest in forest soils followed by grassland, horticulture, agriculture, barren land and lowest in eroded land. The decrease of LC pool with soil depth was distinct. The MBC in the surface soil (0-20 cm) was highest in forest followed by grassland, horticulture, agriculture, barren and lowest in eroded lands. The decrease of MBC with soil depth was conspicuous. The TC content in the surface soil (0-20 cm) was highest in forest soils and lowest in eroded soils followed by forest, grass, horticulture, agriculture, barren and eroded lands. There was a notable decrease in TC with depth in all land use systems.

Relationship between soil properties and available nutrients

The available macro nutrients in soil (N, P, K and S) were positively correlated with pH, EC, CaCO_3 , silt, clay and exchangeable Mg at surface and sub surface soil depth. The N, P, K and S were negatively correlated with sand and CEC. The available micro nutrients in soil (Fe, Mn, Zn and Cu) were positively correlated with pH, EC, silt, clay, CEC, exchangeable Ca and Na. The Zn was negatively correlated with exchangeable Mg in soils under different land use systems.

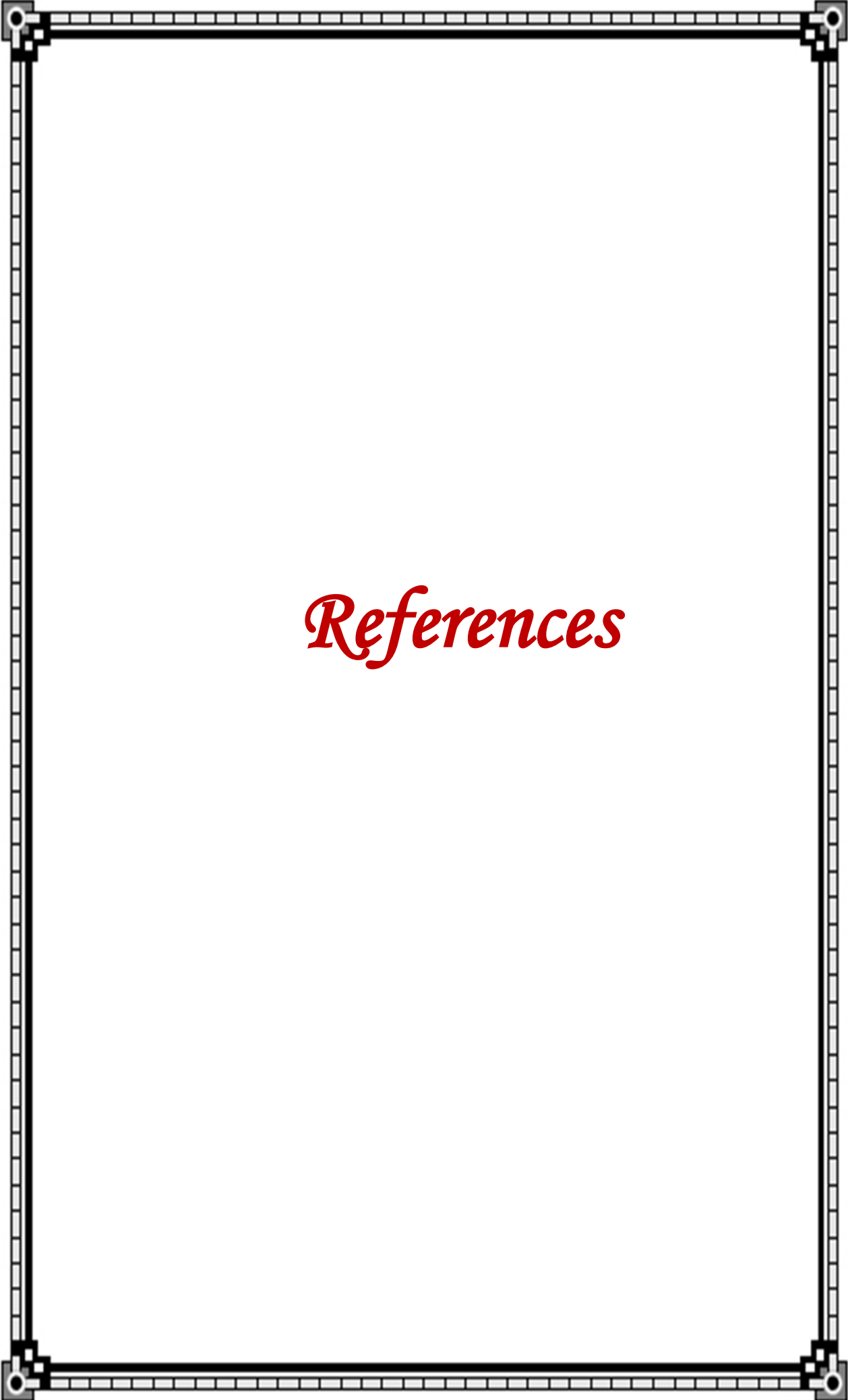
Relationship between soil properties and Carbon Pools

The SOC were positively correlated with pH, EC, CEC, CaCO_3 , clay, exchangeable Mg and Na at surface and sub surface soil depth under different land use systems. The WSOC was positively correlated with pH, CEC, CaCO_3 , silt and exchangeable Na. The LC was positively correlated with pH, EC, CaCO_3 and CEC. The MBC was also positively correlated with pH, EC, CEC and CaCO_3 . Similarly, TC was positively correlated with pH, CEC and CaCO_3 , however, negatively correlated with sand and clay content in soil under different land use system.

Conclusion

The result of the study concluded with respect to all the parameters taken into consideration under the topic “Spatial availability of soil nutrients and carbon pools under different land uses in hilly zone of Doda district of Jammu and Kashmir” as here under.

- Land use systems and soil depth influenced the soil physico-chemical properties and available nutrients.
- The spatial variability of available nutrients in soils suggested that some land use system such as barren, eroded and agriculture required judicious application of organic manuriers as well as inorganic fertilizer to sustain soil health and improving productivity of concerned land use systems.
- With regards to different land use systems, it is observed that eroded and barren land use system were found deficient in major and micro nutrients which required judicious and balanced application of nutrients through organic and inorganic fertilizers to attain the higher crop productivity.
- Land use systems significantly influenced the soil organic carbon pools.
- Different land use systems showed highest accumulation of the various carbon pools in the surface layer.
- Labile carbon was more prevalent under forest land use system followed by grass land use system, horticulture land use system, agriculture land use system, barren land use system and eroded land use system.
- Carbon pools were positively and significantly correlated with silt, CEC and WHC.
- Sand, bulk density and CaCO_3 showed a negative and significant correlation with soil carbon pools.
- There was a strong correlation of carbon pools with physico-chemical properties under different land uses system in the surface soils.



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Vita

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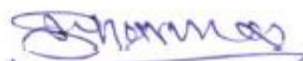
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CERTIFICATE-IV

Certified that all the necessary corrections as suggested by the External Examiner and the advisory committee have been duly incorporated in the thesis entitled **"Spatial variability of soil nutrients and carbon pools under different land uses in hilly Zone of Doda district of J&K"** submitted by **Manoj Kumar**, Registration No. **J-12-D-163-A**.



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