

**SOIL FERTILITY STATUS AS INFLUENCED  
BY LAND USE IN BANKA DISTRICT OF  
BIHAR**

**By  
AMARJEET KUMAR**



**A THESIS  
SUBMITTED IN PARTIAL FULFILLMENT OF THE  
REQUIREMENTS FOR THE AWARD OF THE DEGREE  
OF**

**Master of Science in Agriculture  
(Soil Science and Agricultural Chemistry)**

**DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL  
CHEMISTRY**

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**BIHAR AGRICULTURAL UNIVERSITY, SABOUR  
BHAGALPUR - 813 210  
2016**

**M/SSAC/182/BAC/2014-15**

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**Place: Sabour**

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**ABSTRACT**

Increasing population pressure has historically resulted in land use change from natural forest to cultivated and grazing land with subsequent changes. Land use changes due to deforestation, conversion of rangeland to cropland and cultivation are known to result in changes in soil fertility. Handling suitable land use systems can help in sequestering carbon in the soil and ultimately decline the ill-effects of global warming. The Banka district is located in South Bihar Alluvial plain zone (i.e. Agro climatic Zone IIIA) of Bihar. The major land use types found in Banka district are forests (43310ha), cultivated land (16040 ha), grazing lands (1700 ha) and orchards (7300 ha). The agricultural productivity of Banka district is low due to undulating terrain and lack of irrigation facilities and also unstable due to extreme changes in weather conditions. The present study was planned to evaluate the effects of different land uses on the various soil fertility parameters and active pools of carbon in Banka district of Bihar. To fulfill the objective, triplicate soil samples were collected from six locations across four land use systems viz. forests, grazing, cultivated and orchards lands from two soil depths (0-15 and 15-30 cm). Results show that bulk density was highest in the cultivated land ( $1.59 \text{ Mg m}^{-3}$ ) and lowest in the forest lands ( $1.52 \text{ Mg m}^{-3}$ ). The aggregate stability has found in the order cultivated < grazing < orchard < forest for both surface and subsurface soil samples.

The soil pH under different land uses was slightly acidic but in case of cultivated land it was approaching towards normal pH. Soil organic carbon (SOC) at the 0-15 cm and 15-30cm soil depth in the cultivated lands was 47, 23 and 13; and 37,12 and 12 per cent lower than the forests, orchards and grazing lands ; in the same order. In case of macronutrients the trend towards nutrient availability was as forests > orchards > grazing > cultivated lands. Similar trend was also observed in case of micronutrients Mn, Fe, Cu. In surface soil, Zn was the highest in cultivated land and was the lowest in grazing and orchards lands. Among the different active carbon pools, the highest water soluble carbon (WSC), water soluble carbohydrate (WSCHO), Potassium permanganate oxidizable carbon (PmOC) and soil microbial biomass carbon (SMBC) were recorded in forest soils followed by orchards, grazing and cultivated land. Overall, the soil fertility was found decline in various land use as compared to the forests.

Dr. Y.K. Singh  
Major Advisor

Amarjeet Kumar  
Student signature

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## List of abbreviations

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|              |          |   |
|--------------|----------|---|
| <b>%</b>     | <b>:</b> | <b>Percentage</b>                                   |
| <b>°C</b>    | <b>:</b> | <b>Degree Celsius</b>                               |
| <b>°E</b>    | <b>:</b> | <b>Degree East</b>                                  |
| <b>°N</b>    | <b>:</b> | <b>Degree of North</b>                              |
| <b>ANOVA</b> | <b>:</b> | <b>Analysis of Variance</b>                         |
| <b>BD</b>    | <b>:</b> | <b>Bulk density</b>                                 |
| <b>C</b>     | <b>:</b> | <b>Carbon</b>                                       |
| <b>CEC</b>   | <b>:</b> | <b>Cation exchange capacity</b>                     |
| <b>cm</b>    | <b>:</b> | <b>Centimeter</b>                                   |
| <b>Cu</b>    | <b>:</b> | <b>Copper</b>                                       |
| <b>DTPA</b>  | <b>:</b> | <b>Diethylene Triamine Penta acetic acid</b>        |
| <b>DW</b>    | <b>:</b> | <b>Distilled water</b>                              |
| <b>EC</b>    | <b>:</b> | <b>Electrical conductivity</b>                      |
| <b>FAO</b>   | <b>:</b> | <b>Food and Agricultural Organization</b>           |
| <b>Fe</b>    | <b>:</b> | <b>Iron</b>   |
| <b>g</b>     | <b>:</b> | <b>gram</b>   |
| <b>ha</b>    | <b>:</b> | <b>hectare</b>                                      |
| <b>ICAR</b>  | <b>:</b> | <b>Indian Council of Agricultural<br/>Research</b>  |
| <b>kg</b>    | <b>:</b> | <b>kilogram</b>                                     |
| <b>LSD</b>   | <b>:</b> | <b>Least significance difference</b>                |
| <b>MWD</b>   | <b>:</b> | <b>Mean weight diameter</b>                         |
| <b>MWHC</b>  | <b>:</b> | <b>Maximum water holding capacity</b>               |
| <b>Mn</b>    | <b>:</b> | <b>Manganese</b>                                    |
| <b>mm</b>    | <b>:</b> | <b>millimeter</b>                                   |
| <b>mg</b>    | <b>:</b> | <b>milligram</b>                                    |
| <b>N</b>     | <b>:</b> | <b>Nitrogen</b>                                     |
| <b>NARP</b>  | <b>:</b> | <b>National Agricultural Research Project</b>       |
| <b>OC</b>    | <b>:</b> | <b>Organic carbon</b>                               |
| <b>OM</b>    | <b>:</b> | <b>Organic matter</b>                               |
| <b>P</b>     | <b>:</b> | <b>Phosphorus</b>                                   |
| <b>PmOC</b>  | <b>:</b> | <b>Potassium permanganate oxidisable<br/>carbon</b> |
| <b>SMBC</b>  | <b>:</b> | <b>Soil microbial biomass carbon</b>                |
| <b>SOC</b>   | <b>:</b> | <b>Soil Organic Carbon</b>                          |
| <b>SOM</b>   | <b>:</b> | <b>Soil organic matter</b>                          |
| <b>TOC</b>   | <b>:</b> | <b>Total organic carbon</b>                         |
| <b>WSC</b>   | <b>:</b> | <b>Water soluble carbon</b>                         |
| <b>WSCHO</b> | <b>:</b> | <b>Water soluble carbohydrate</b>                   |
| <b>Zn</b>    | <b>:</b> | <b>Zinc</b>   |

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## *Introduction*

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Soil fertility is the inherent capacity of a soil to supply the essential plant nutrients. It is the primary division whose maintenance is a major concern in tropical parts of world like India where fast decomposition of organic matter lowers the soil organic carbon content. Lowering the organic carbon content in the soil deteriorates the fertility of the soil. In traditional farming system, soil fertility was naturally maintained due to traditional management practices such as use of crop residues, animal manure and leaving land fallow for few years. But, now a days intensive cultivation and improper management practices have made soil unsuitable for production unless inputs external like fertilizers and manures are added.

Soil fertility is a function of several factors and processes, some socio-economic and some ecological; for instance, parent material, natural inputs & outputs to and from the system, and management practices. Land use is the prime management intervention in the system that can result in significant variation in soil physico-chemical properties. Land use pattern and agricultural practices, especially cultivation of deforested land may rapidly deteriorate soil fertility. A recent report of FAO (2000) states that about 20 per cent of the total cultivable land in the world is declining in fertility and impacting about a quarter of the world's population. The effects of different land use systems and their associated management practices on soil properties have been studied and reported (Mulugeta, 2004; Wakene and Heluf, 2004; Ashagrie *et al.* 2005). Different land use systems have also been reported to impact labile carbon pools (Sharma *et al.* 2014). Increasing population pressure has historically resulted in land use change from natural forest to cultivated and grazing lands with subsequent changes. Land use changes such as deforestation, conversion of rangeland to cropland and cultivation are known to result in changes in soil physico-chemical properties. Land use pattern also plays a vital role in governing the nutrient dynamics and fertility of soils (Venkatesh *et al.* 2003). Thus, every effort should be directed to maintain the soil fertility through sustainable use of the ecosystem.

The present investigation has been targeted for Banka district located in South Bihar Alluvial Plain Zone (i.e. Agro climatic Zone IIIA) of Bihar (Ghosh, 1996). The major land use

types found in Banka district are forests (43310 ha), cultivated land (160040 ha), grazing lands (1700 ha) and orchards (7300 ha). The agricultural productivity of Banka district is low due to undulating terrain and lack of irrigation facilities. However, there is no published literature regarding the comparative nutrient status across various land use systems in Banka. Moreover, no comparative study on the active carbon pools has been attempted earlier. This information is important to address the issue of agro-ecosystem transformation and sustainable land productivity. Agricultural sustainability requires periodic evaluation of soil fertility status which is important in understanding the factors that impose serious constraints to crop production under different land use types and for adoption of suitable land management practices (Chimdi *et al.* 2012). This study was planned to investigate the influence of different land use system on soil fertility status and assess the active carbon pools in the soils across various land use systems. This study will enable us to have an idea about the sustainability of various land use systems as well as the transformation in land uses. Keeping in mind the above facts, the present study was carried out with following objectives:

- ❖ To study the soil fertility status across different land uses in Banka.
- ❖ To assess the active carbon pools in the soils across various land use systems.

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## *Review of Literature*

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Changes in land use and soil management can have a marked effect on soil physical and chemical properties. The physical and chemical properties of soils in the experimental area vary from one land use to other land use type due to the impact of cultivation, grazing and tree planting activity.

### **2.1 Soil Physical Properties**

Adaptability to cultivation and the extent of biological activity in the soil is determined by the physical properties of soils. Soil physical properties also establish the nutrient and water supplying capacity to plants. Many soil physical properties change with changes in land use system and its management practices followed (Sanchez, 1976).

#### **2.1.1 Soil texture**

Soil texture determines a number of physical and chemical properties of soils. It affects the nutrient and water supplying capacity as well as microbial activities. Bezabih *et al.* (2014) reported in Enset (*Enset ventricosum*) farm land that different land uses had no significant variation in sand and silt content in depths. But, there was relatively higher proportion of sand and lower proportion of clay content in the forest land as compared to cultivated land. Chauhan *et al.* (2014) reported that no variation occurs between the sand, silt and clay fractions of forest land and pasture land. Soil texture is one of the inherent soil physical properties less affected by management. In the subsurface horizons, however, slight differences were noticed. The clay percentage increased whilst the sand decreased from the surface to the subsurface horizons in all land use systems observed by Gailyson (2013). Over a very long period of time, pedogenic processes such as erosion, deposition, eluviation and weathering can change the textures of various soil horizons (Forth, 1990; Brady and Weil, 2002).

### **2.1.2 Bulk density**

Bulk density (the mass of a unit volume of dry soil) is required for the determination of compactness or looseness, as a measure of soil structure. Bulk density one of the major role play in the soil fertility. Bulk density was highly significantly affected by the interaction effect of land use and soil depth where the highest ( $1.3 \text{ g cm}^{-3}$ ) was observed on the surface layer of grazing land and lowest ( $0.9 \text{ g cm}^{-3}$ ) on the surface layer of forest land, which might be due to the effects of high compaction by grazing animals in grazing and cultivated lands and high OM content in forest land (Habtamu *et al.* 2014). Chauhan *et al.* (2014) reported that soil bulk density was not significantly affected by land use systems in western Chitwan soils. However, the highest soil bulk density ( $1.41 \text{ g cm}^{-3}$ ) was observed from cereal based upland and the lowest ( $0.99 \text{ g cm}^{-3}$ ) from the pasture land. According to them, highest soil bulk density from cereal based uplands could be due to the higher sand content and destruction of soil aggregates by intensive tillage operation. Aminu *et al.* (2013) studied bulk density variation in different wheat cultivated farmland and found increasing trend as the depth increases. Papine *et al.* (2011) and Aminu *et al.* (2013) observed the effect of land use with soil depths and obtained similar trend in vertical distribution of bulk density in different land use. Mulugeta (2004) reported that the bulk density of cultivated soils was higher than the bulk density of forest soils. Similarly, Ahmed (2002) reported that soil bulk density under both cultivated and grazing lands increased with increasing soil depth. The changes in the physical soil attributes on the farm fields can be attributed to the impacts of frequent tillage and the decline in OM content of the soils.

### **2.1.3 Soil Aggregation**

Land use system is one of the key factors influencing soil aggregates stability. This was attributed to positive impact of the vegetation on soil health due to addition of organic matter through leaf litter. Furthermore, different types of vegetation cover under different land uses enhance infiltration and offer favorable microclimate (Mohanty *et al.* 2012). Somasundaram *et al.* (2013) reported that MWD of aggregates showed significant variation under different land use systems. He observed that grass land showed larger MWD followed by *Leucaena leucocephala* and mixed forest area. In cropped area showed small MWD whereas in ravinous land higher mean weight diameter. Water stable aggregates were significantly larger in the

forest and pasture soils than in the cultivated soils (Gol, 2009). The % decrease relative to < 0.25 mm aggregate size was 35.0 % for the fallow soil and 23.7% for the cultivated soil. The wet-sieved samples showed that the lowest OC concentration occurred in the 5-2 mm fractions for the fallow soil, the result could be due to loss of organic material binding agents by wet-sieving process. The lowest MWD observed in cultivated soil could be attributed either to the length of cultivation, mineralogy or management system adopted on the soil (Nweke and Nnabude, 2014). Aggregate stability depends on interaction between primary particles and organic constituents to form stable aggregates, which are influenced by various factors related to soil environmental conditions and management practices. Abad *et al.* (2014) indicated that aggregate stability of cultivated soils was significantly lower than that of forested soils.

### **2.1.4 Maximum water holding capacity**

Water holding capacity is the difference between weight of water saturated soil to oven dry soil. Nisar and Lone (2013) reported that WHC of forest soils was found to be significantly different from that of cultivated areas. The water content of forest and grazing land soils gave the highest values though that of grazing land is not significantly different from cultivated land. The soils from eucalyptus plantation had the least value though not significantly different from grazing land observed by (Mesfin, 2013). The increases of soil moisture with depth were correlated positively with the clay fractions of the soils. The relatively higher moisture content in virgin soil site could be attributed to the high clay content of the soils. Brady and Weil, (2002) reported that fine texture soils hold more moisture than coarse-textured soils. Variability in moisture content is higher in soils of virgin soil than in soils of the other land use (Aminu *et al.* 2013). Water holding capacity in forest soil (16-20 %) was highest and for hazelnut soils the lowest (10-14 %). Bulk density plays an important role through its control of the pore space that retains water as reported by Gol, (2009).

### **2.2 Soil Chemical Properties**

Nutrient supplying power of the soil to the plants and microbes is determined by the soil chemical properties. The chemical reactions that occur in the soil affect processes leading to soil fertility build up. Soil minerals inherited from the parent materials over time release chemical elements that undergo various changes and transformations within the soil. Takele *et*

*al.* (2014) reported was significantly varies across forest, grazing and cultivated land use on soil chemical properties.

### **2.2.1 Soil reaction (pH) and electrical conductivity**

pH is an important factor that affect physical, chemical and biological process for nutrient availability. Soil reaction (usually expressed as pH value) is the degree of soil acidity or alkalinity, which is caused by particular chemical, mineralogical and/or biological environment. Soil reaction affects nutrient availability and toxicity, microbial activity, and root growth. Thus, it is one of the most important chemical characteristics of the soil solution because both higher plants and microorganisms respond so markedly to their chemical environment. The pH values of bulk soils of the natural forest land were significantly higher ( $P < 0.05$ ) than the soils of other land uses, i.e., cultivation, grazing and eucalyptus plantation land uses (Mesfin, 2013). The soil pH could be categorized as slightly acidic under forest and maize fields whereas that of grassland was moderately acidic, following the classification described by (Brady and Weil, 2002). Soil pH was statistically similar in all the land use types. Soils under cultivation had higher pH than the soils under forest and pastureland, but this rate had not significant difference between cultivated land and pasture land (Abad *et al.* 2014). The degree and nature of soil reaction influenced by different anthropogenic and natural activities including leaching of exchangeable bases, acid rain, decomposition of organic materials, application of commercial fertilizers and other farming practices (Rowell, 1994; Miller and Donahue, 1995).

Electrical conductivity (EC) is a measure of salinity. It is a quicker and more accurate method in order to determine the salt concentration (Bohn *et al.* 2001). Excessive accumulation of soluble salts converts soils to salt affected soils and the process leading to accumulation of salts are common in arid and semiarid regions where rainfall amount is insufficient to leach soluble salts. EC during dry season had its highest reading in the farm soils ( $5.74 \text{ m S m}^{-1}$ ) at a depth of 0-15 cm followed by the Rubber Plantation Soils ( $5.52 \text{ mS m}^{-1}$ ) a at depth of 0 -15 cm (Martin *et al.* 2016). The EC values of the natural forest, pastureland and agriculture soils varied from  $0.57 \text{ d Sm}^{-1}$  in pastureland to  $0.66 \text{ d Sm}^{-1}$  in agricultural land that changing forest to cultivated land has increased EC values in their studied area (Abad *et al.* 2014).

### 2.2.2 Soil organic carbon

Soil organic carbon (SOC) is one of the most important chemical properties which is greatly influenced by land use type on a long-term bases. The highest organic carbon content resulted in higher organic matter content for soils of forest land while other land uses only rated medium levels (Mesfin, 2013). Mishra *et al.* (2015) reported that SOC is comparatively higher ( $>0.5 \text{ g kg}^{-1}$ ) in surface horizons of upper land than lower land. Kiflu and Beyene (2013) observed significant differences in SOC content of soils among the different land use systems. The mean values of soil organic carbon across the different land use types and slope zones were 2.70, 3.83 and 4.24 % for cultivated, grazing and forest area (Bezabih *et al.* 2014). Using of N fertilizer and animal manure in corn fields to gather more products, increases SOC in cultivated soils (Gol, 2009). The continuous wheat soils had the lowest SOC concentrations, with uniform distribution across sampled layers (at both Soveria Simeri and S. Quirico sites), TOC were near 1.0% and 0.1%, respectively Papini *et al.* (2011). Sharma *et al.* (2014) found that agricultural and degraded lands had up to 25% lower SOC stocks than forest soils, to the top half a meter layer of soil. The typical decrease of carbon content with depth was the sharpest for agricultural soils.

Gregorich *et al.* (1995) reported that the concentration of organic carbon (OC) in the forest soil decreased with depth by more than 10-fold in the surface 30 cm, from  $139 \text{ gkg}^{-1}$  soil in the 0-15 cm layer to  $12 \text{ gkg}^{-1}$  soil in the 15-30 cm layer. The surface layer is most relevant to assess the impact of management practices on soil OM, because surface soils are easily modified directly by cultivation.

### 2.2.3 Cation exchange capacity

The Cation exchange capacity (CEC) of soils is defined as the capacity of soils to adsorb and exchange cations (Brady and Weil, 2002). Cation exchange capacity is an important parameter of soil because it gives an indication of the type of clay minerals present in the soil, its capacity to retain nutrients against leaching and assessing their fertility and environmental behavior. Generally, the chemical activity of the soil depends on its CEC. The CEC of a soil is strongly affected by the amount and type of clay, and amount of OM present in the soil (Curtis and Courson, 1981). The rubber plantation soils had more capacity for cation exchange during dry season when compared to farmland and deforested land (residential area) soils while on

assessment during rainy season, rubber plantation soil had CEC that was less than both the farmland soils and deforested soils (Martin *et al.* 2016). Cation Exchange Capacity was significantly different between control (Virgin land) and other land uses with the exception of farmland by (Aminu *et al.* 2013). Soil CEC varied among land uses in both the magnitude and the distribution across the sampled layers. In general, the soils under cultivation and the soil under grazing had a uniform CEC throughout the profile sampled, while the soils under permanent grass and those under Mediterranean bush exhibited more or less pronounced decreases in CEC with increasing depth (Papini *et al.*, 2011). Cations removed from the exchange sites often are replenished rapidly from other sources, such as OM decomposition, mineral weathering, or release of ions fixed within the layers of clay minerals. Generally, processes that affect texture (such as clay) and OM due to land use changes also affect CEC of soil. Therefore, it is necessary to study and evaluate soil chemical properties to avoid soil nutrient depletion and degradation, and to sustain production.

#### **2.2.4 Available nitrogen**

Nitrogen (N) is the essential plant element taken up by plants in greatest quantity next only to carbon, oxygen and hydrogen; It is one of the most deficient elements in the tropics for crop production (Sanchez, 1976; Mengel and Kirkby, 1987; Mesfin, 1998). The available nitrogen is comparatively higher in the surface soil, which is because of the higher amount of organic carbon in those surface soils. (Mishra *et al.* 2015). Nitrogen content of soil was significantly affected by the land use systems. Total soil nitrogen content was the highest (0.23 %) from pasture land and the lowest (0.08 %) was from farmer's field (Chauhan *et al.* 2014). Su *et al.* (2004) reported significant effect of short term cultivation on soil Carbon, Nitrogen and biological properties which were lower than that in the native grassland soil. The N content is lower in continuously and intensively cultivated and highly weathered soils of the humid and sub humid tropics due to leaching and in highly saline and sodic soils of semi-arid and arid regions due to low OM content (Tisdale *et al.* 1995). Wakene (2001) reported that there was a 30% and 76% depletion of total N from agricultural fields cultivated for 40 years and abandoned land, respectively, compared to the virgin land in Bako area, Ethiopia. Average total N increased from cultivated to grazing and forest land soils, which again declined with increasing depth from surface to subsurface soils (Nega, 2006). The

considerable reduction of total N in the continuously cultivated fields could be attributed to the rapid turnover (mineralization) of the organic substrates derived from crop residue (root biomass) whenever added following intensive cultivation (McDonagh *et al.* 2001). Moreover, the decline in soil OC and total N, although commonly expected following deforestation and conversion to farm fields, might have been exacerbated by the insufficient inputs of organic substrates from the farming system (Mulugeta, 2004). The same author also stated that the levels of soil OC and total N in the surface soil (0-10 cm) were significantly lower and declined increasingly with cultivation time in the farm fields,

### **2.2.5 Available phosphorus**

Phosphorus (P) is known as the master key to agriculture because lack of available P in the soils limits the growth of both cultivated and uncultivated plants (Foth and Ellis, 1997). Following N, P has more wide spread influence on both natural and agricultural ecosystems than any other essential element. In most natural ecosystems, such as forests and grasslands, P uptake by plants is constrained by both the low total quantity of the element in the soil and by very low solubility of the scarce quantity that is present (Brady and Weil, 2002). Phosphorus (P) is also an essential part of the process of photosynthesis, involved in the formation of all oils, sugars, starches, etc. The available phosphorus content is higher in the surface soil and decreases down the depth (Mishra *et al.* 2015). The average values of available phosphorus were 4.81, 7.89, and 10.88 mg kg<sup>-1</sup> for cultivated, grazing and Enset (*Enset ventricosum*) farm land respectively (Bezabih *et al.* 2014). There was no significant difference in available P between pasture and forest lands (Chauhan *et al.* 2014). Acid soils are known to have low P contents, not only due to the inherently low available P content, but also due to the high P fixation capacity of the soils observed by (Murphy, 1968; Eylachew, 1987).

### **2.2.5 Available potassium**

Available potassium present in soil solution which is easily available to the plant. Sharma (2013) reported that available potassium in the acid soil of Nagaland to rate as medium in forest land and low in cultivated land .The lowest amount of available soil potassium was determined in the soils of cereal based lowlands compared to other land use systems due to higher leaching loss of potassium from soil surface, more K harvest from the soil, crop

intensification and low external input. Kanwar, (1976) reported the higher K leaching loss from humid tropics as a major factor of limiting productivity but the leaching under natural vegetation was low.

### **2.2.6 Micronutrients (Fe, Mn, Zn and Cu)**

The term micronutrients refer to a number of elements that are required by plants in very small quantities. This term usually applies to nutrient elements that are contained in plant tissues in amounts less than 100 mg kg<sup>-1</sup> (Foth and Ellis, 1997). According to the some authors, the four essential micronutrients that exist as cations in soils unlike to boron and molybdenum are zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn). Adsorption of micronutrients, either by soil OM or by clay-size inorganic soil components is an important mechanism of removing micronutrients from the soil solution (Foth and Ellis, 1997). There was significant difference in Zn content between control (virgin land) and farmland, mechanic site and industrial area while in residential area the results were statistically similar with the Virgin land. Variability in Zn content in soils of the different land use was much more in Industrial area . Zn content in soils of the different land use is generally low (Aminu *et al.* 2013). Yeshaneh (2015) reported that the contents of available micronutrients (Fe, Mn, Zn and Cu) under the different land management practices were significantly different in forest, grazing and cultivated land in sandy loam soil.

### **2.3 Active or labile carbon pool**

Conversion in land use from forest land to cultivated land can have detrimental effect on soil carbon pool. Forest is a reserve of soil carbon due to addition of litter fall and root residues continuously that contribute largest input of carbon to the soil (Smith, 2007).

The amount of microbial biomass although comprise a small amount of active soil organic matter, reflects the total organic matter content within the living microbial component. It comprises 2-3 % of total soil carbon (Jenkinson and Ladd, 1981). It is a good measure of the state of edaphic environment that is highly sensitive to changes in land use and management practices. The soil microbial biomass carbon (SMBC) content was more in the forest (107.9 mg kg<sup>-1</sup> soil) followed by horticulture (88.5 mg kg<sup>-1</sup> soil), agriculture (69.7 mg kg<sup>-1</sup> soil) and degraded land (76.7 mg kg<sup>-1</sup> soil), as reported by Sharma *et al.* (2014). They recorded similar trend for the lower depths with lowest mean values being recorded in lowest depth. SMBC

was found lower in cultivated or agriculture land due to management practices like tillage that enhanced soil aeration and, through exposure of organic matter, otherwise aggregate-protected to microbial attack, accelerates organic carbon oxidation (Beare *et al.*, 1994). Kaul *et al.*, (2010) observed that SMBC was higher by 42 % in forest based systems as compared to agriculture based mono-cropping system. Sensitiveness of SMBC to change in land use results in its inclusion as an influencing factor for crop productivity besides nutrient cycling.

Water soluble carbon (WSC) appears to be the immediate organic substrate for soil microorganisms (McGill *et al.* 1986). It is one of the active components of soil organic carbon pool (Ghani *et al.* 1999, 2003; Chaudhari *et al.* 2013). Changes in WSC which is the most labile and mobile form of soil organic carbon, have received much less attention. Few studies supported more WSC in agriculture/cultivated land use system while few reported more in forest land use system. According to the supporters of agriculture or cultivated land use system, there is more microbial activity in this land use system as compared to forest land use system. But, the supporters of forest land use system reasoned that more organic matter addition in this system as compared to agriculture or cultivated land. Sharma *et al.* (2014) recorded WSC ranging from 12.8 to 100.0, 14.1 to 86.4, 7.9 to 63.5 and 6.9 to 78.0 mg kg<sup>-1</sup> of soil for agriculture, forestry, horticulture and degraded lands, respectively in the surface layer.

Water soluble carbohydrate (WSCHO) is a significant component of active pool of soil organic carbon. It comprises of 5-20 % of soil organic matter. It plays an important role in the formation and stabilization of soil structure (Cheshire, 1979). They also increase the nutrient supplying capacity of soil and soil aggregation (Yousefi *et al.* 2008). Cultivation/agriculture reduced the WSCHO as reported by Riffaldi *et al.* (2003). Addition of organic manure and the higher return of crop residues in the soil increase the carbohydrate content (Debosz *et al.* 2002; Xiao *et al.* 2006 and Yousefi *et al.* 2008).

Potassium permanganate oxidizable carbon (PmOC) is the active form of carbon. It is sensitive to land use and the management practices and thus parameter of soil health. It can be an important tool for determining the sustainability of agro-ecosystem (Wang *et al.* 2014). Sharma *et al.* (2014) recorded PmOC in the surface layer that was ranged from 304.7 to 1494.7, 473.5 to 2026.9, 205.9 to 1011.2 and 145.7 to 1140.6 mg kg<sup>-1</sup> soil for agriculture, forest, horticulture and degraded lands, respectively. Mean PmOC was highest in forest soils followed by agriculture, horticulture, and degraded lands. The sub-surface PmOC content was

highest in forest soils; however, it was followed by horticultural soils and then agriculture. PmOC comprises of 10-20 % of total organic carbon (TOC) as reported by Benbi *et al.*, 2015. The proportion of PmOC varied from 1.66 to 23.2 % with mean value of 9.16 % of total soil organic carbon (Verma *et al.* 2013). The amount of PmOC decreases with increase in soil depth. Cultivation results in 21–36 % depletion in TOC as compared to uncultivated soils Benbi *et al.* (2015). TOC are slightly lower than those (30–60 %) reported earlier for a variety of soils in different agro climatic regions of India (Lal, 2004).

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## *Materials and Methods*

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### **Site Description**

#### **3.1 Location**

The study was targeted for Banka district which is located in South Bihar Alluvial Plain Zone i.e. the Agroclimatic Zone IIIA of Bihar (Ghosh, 1996).

#### **3.2 Climate**

##### **Agro-Climatic or Ecological Zone**

Agro Ecological Sub Region (ICAR) Eastern Plain, Hot Subhumid (moist) Eco-sub region Agro-Climatic Zone (Planning Commission), Middle Gangetic Plain Region (IV). Agro-Climatic Zone (NARP) South Bihar Alluvial Plain Zone. List all the districts or part there of falling under the NARP Zone Sheikhpura, Munger, Jamui, Lakhisarai, Bhagalpur & Banka Geographic coordinates of district headquarters. Latitude, Longitude and Altitude 24°0 30' to 25° 008' N, 86° 030' to 87° 012' E and 43 m respectively.

##### **Rainfall (RF)**

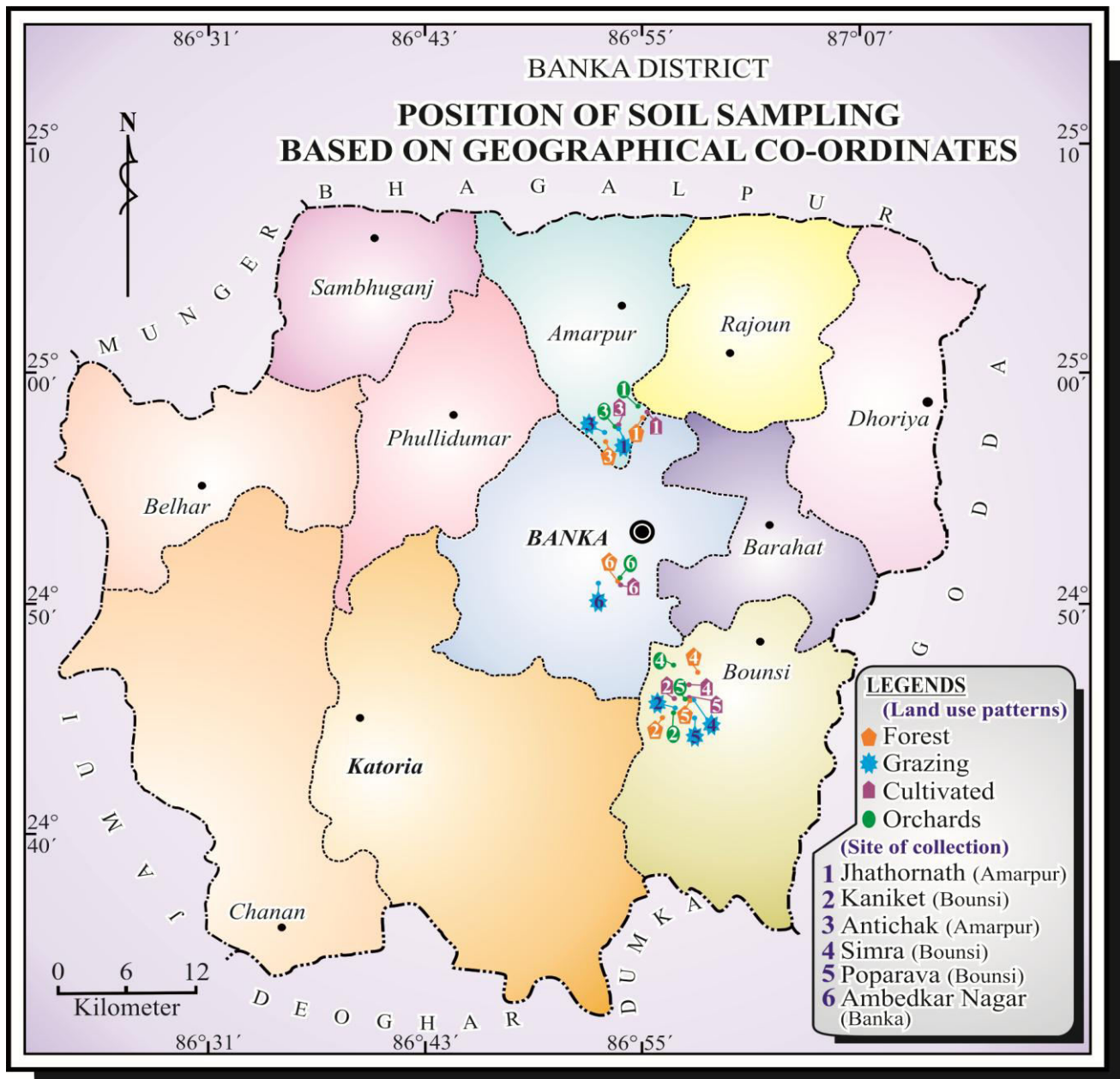
Normal RF (mm) Normal Onset Normal Cessation south-west monsoon (June-September): 903.7 mm after that; 2<sup>nd</sup> week June to 2<sup>nd</sup> Week of September north-east monsoon (October-December): 180.3 mm; winter (January-March) 14.0 mm; Summer (April-May) 88.0 mm and average annual rain fall 1170 mm.

The cultivated land accounts for an average of about 40 % and the grazing and forest lands and area closure sites together account for about 50 % of the Banka area. The large varieties of crops, such as Emmer wheat, barley, maize and pulses. The major crops grown during the main rainy season are viz: rice, wheat, maize vegetable etc.

3.3 Soil Sampling

Table: 1. Selection of sites for soil sampling

| Land use pattern | Site of collection |                | Block / sub-division | Geographical co-ordinate |                 |              |
|------------------|--------------------|----------------|----------------------|--------------------------|-----------------|--------------|
|                  |                    |                |                      | Latitude                 | Longitude       | Altitude (m) |
| Forest           | 1.                 | Jhathornath    | Amarpur              | 24°58' 18.1"N            | 86 55 26.3E     | 61           |
|                  | 2.                 | Kaniket        | Bounsi               | 24° 45'36.5" N           | 86° 56'92.3" E  | 129          |
|                  | 3.                 | Antichak       | Amarpur              | 24°57'63.7" N            | 86° 53'65.6" E  | 71           |
|                  | 4.                 | Simra          | Bounsi               | 24° 47'39.5" N           | 86° 58'99.5" E  | 109          |
|                  | 5.                 | Poparava       | Bounsi               | 24° 45'91.0" N           | 86° 57'72.2" E  | 141          |
|                  | 6.                 | Ambedkar Nagar | Banka                | 24° 50'97.1"N            | 86° 53'70.5" E  | 85           |
| Grazing          | 1.                 | Jhathornath    | Amarpur              | 24°57'61.9" N            | 86° 56'97.0" E  | 59           |
|                  | 2.                 | Kaniket        | Bounsi               | 24° 45'40.5" N           | 86° 53'65.2" E  | 126          |
|                  | 3.                 | Antichak       | Amarpur              | 24° 57'43.5" N           | 86° 59'0.3" E   | 109          |
|                  | 4.                 | Simra          | Bounsi               | 24° 45'92.0" N           | 86° 57'70.2" E  | 141          |
|                  | 5.                 | Poparava       | Bounsi               | 24° 45'40.5" N           | 86° 56'97.0" E  | 129          |
|                  | 6.                 | Ambedkar Nagar | Banka                | 24° 50'98.4"N            | 86° 53'69.5" E  | 85           |
| Cultivated       | 1.                 | Jhathornath    | Amarpur              | 24°58'46.8" N            | 86°55'.107" E   | 50           |
|                  | 2.                 | Kaniket        | Bounsi               | 24° 45'48.5" N           | 86° 56'958" E   | 119          |
|                  | 3.                 | Antichak       | Amarpur              | 24°57'74.1" N            | 86° 53'.921" E  | 69           |
|                  | 4.                 | Simra          | Bounsi               | 24° 46'32.0" N           | 86° 57'634" E   | 109          |
|                  | 5.                 | Poparava       | Bounsi               | 24° 45'92.5"N            | 86° 57'692" E   | 140          |
|                  | 6.                 | Ambedkar Nagar | Banka                | 24° 50' 99.6" N          | 86° 53' 74.8"E  | 85           |
| Orchards         | 1.                 | Jhathornath    | Amarpur              | 24°58' 79.2" N           | 86°54' 99.6" E  | 54           |
|                  | 2.                 | Kaniket        | Bounsi               | 24° 45'27.9" N           | 86° 56'86.8" E  | 128          |
|                  | 3.                 | Antichak       | Amarpur              | 24°57'64.0" N            | 86° 53'64.8" E  | 69           |
|                  | 4.                 | Simra          | Bounsi               | 24° 47'29.5" N           | .86° 56'80.2" E | 104          |
|                  | 5.                 | Poparava       | Bounsi               | 24° 45'57.0"N            | 86° 57'12.0" E  | 141          |
|                  | 6.                 | Ambedkar Nagar | Banka                | 24° 51'02" N             | 86° 53'73.9" E  | 84           |



**Figure 1: Position of soil sampling based on geographical co-ordinates**

#### **Collection and preparation of soil samples**

Six different locations were identified in the study area by geographical position system (Table 1 & Figure 1). Soil samples were collected from all four different land use systems viz. forest, grazing, cultivated and orchards, fairly adjacent to each other, at each of these locations which makes the total number of sampling sites 24 (i.e. 6 locations  $\times$  4 land uses). Triplicate soil samples were collected from each location. Agricultural system included samples from predominantly maize–wheat/mustard system, whereas mango, guava and jack fruit orchards

represented the horticultural system in this study area. Agriculture in these areas is being carried out for well over 100 years, and the cultivable land has been passed on from ancestors to present generations. On the other hand the orchards are only 50-60 years old. The land for human use has been claimed from forests. Forests were mixed and changed with altitude in Banka district.

At the beginning, a general visual field survey of the area was carried out to have a general view of the variations in the study area. Representative soil sampling sites were then selected based on vegetation and cultivation history. Following the general visual survey to select six different site, four representative fields were selected at each location to represent the land use types (cultivated, forest, grazing and orchards lands). Triplicate soil sample were collected from each site from the depths of 0-15 cm and 15-30 cm separately each in a radial sampling scheme using an auger (Wilding, 1985). During collection of samples; dead plants, furrow, old manures, wet spots, areas near trees and compost pits were excluded. This was done to minimize differences, which may arise because of the dilution of soil OM due to mixing through cultivation and other factors. Samples were air-dried, mixed well and ground to pass through a 2 mm sieve for the analysis of selected soil physical and chemical properties. Separate soil core samples from the 0-15 cm and 15-30 cm depths were taken with a sharp-edged steel cylinder forced manually into the soil for bulk density determination. Global Positioning System (GPS) were used to identify the geographical locations.

### **3.4 Soil Analysis**

#### **3.4.1. Physical properties**

The following important properties of the soil under study were determined-

##### **3.4.1.1. Mechanical analysis**

Particle size of soils was estimated by Hydrometer method as described by Bouyoucos (1962). A 50 gram of soil was weighted into a beaker, 60 mL of 6% H<sub>2</sub>O<sub>2</sub> and 40 mL water was added and stirred for 10 minutes on water bath. Suspension was transferred into a cylinder and makes upto 1 litre and shakes it vigorously for 5 minutes. Hydrometer was placed in suspension and reading was taken exactly after 4 minutes and 2 hours. Sand, silt and clay content of the soils were calculated and textural class was determined by using USDA textural triangle.

**3.4.1.2. Maximum water holding capacity**

Maximum water holding capacity of soil was determined by Keen and Rockzowski's method (Baruah & Barthakur, 1997).

**3.4.1.3. Aggregate size distribution:-**

Aggregate size distribution of soil determined by Wet sieving method (Yoder, 1936).

A 50 g of soil Aggregate size less than 8mm. Arrange the sieve size 5, 2, 1, 0.5, 0.25 and 0.10 mm. run the Yoder apparatus 30 minutes. Collect the wet sample from different sieve in what-man filter paper 1. Kept in oven 105°C for 48-72 hours after take weight.

**3.4.1.4 Bulk density**

Bulk density of soil determined by core method (Uhland, 1949). Collect the soil samples by using core sampler from (0-15 cm) and (15-30 cm) soil depths. soil samples the oven dry weight ( heated at 105°C for 24 hours) of known volume of soil samples is determined and mass per unit volume calculated.

**3.4.2. Chemical properties****3.4.2.1. pH**

pH (H<sub>2</sub>O) of the soil sample was determined in water, soil-water suspension ratio of 1:2 with a glass electrode pH meter (Jackson, 1973). Take 10 g soil in 50 ml beaker and add 20 ml deionized water. Stir with glass rod occasionally for about 30 minutes. Immerse the glass electrode of the pH meter in the soil-water suspension in the beaker.

**3.4.2.2. Electrical conductivity (EC)**

EC of the soil sample was determined in soil-water suspension (1:2) at room temperature by conductivity meter (Jackson, 1973). Weight 10 g soil sample in a 50 ml. beaker. Add 20 ml distilled water in it. (soil:water::1:2). Stir with glass rod occasionally for about 30 minutes. Let the suspension stand till the soil particles settle down. Use the supernatant liquid in the conductivity meter and take reading.

**3.4.2.3. Organic Carbon (OC)**

Organic carbon was determined by wet digestion method (Walkley and Black, 1934). Take 0.5 g of soil in 500 ml conical flask. Add 10 ml of 1N K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub> to it pour slowly 20 ml of conc. H<sub>2</sub>SO<sub>4</sub> and swirl the flask gently. Keep the flask in dark for half an hour. Add 200ml of distilled water, 10 ml ortho-phosphoric acid and pinch of sodium fluoride into the flask and

allow the content cool. Add 2-3 drop of diphenylamine indicator to the flask and titer with ferrous ammonium sulfate (0.5N) solution till the colour changes from dark blue to bottle green.

#### **3.4.2.4. Cation Exchange Capacity (CEC)**

Cation Exchange Capacity was determined by sodium acetate saturation method (Black, 1965). Soil was saturated with sodium acetate (pH 7.0) shaking one hour and centrifuge at 3000 rpm for five minutes repeated three times and wash with ethanol (60 %) three times and finally sodium saturated soil shaking with ammonium acetate (pH 7.0) filter with what-man filter paper 1 and take reading in flame photometer.

#### **3.4.2.5. Available Nitrogen**

Determination of available nitrogen by alkaline potassium permanganate method (Subbiah & Asija, 1956). Take 5 g soil sample into Kjeldahl tube. Add 30 ml of 0.32 %  $\text{KMnO}_4$  and place a 250 ml conical flask containing 25 ml of 2 % boric acid with mixed indicator at end of delivery tube. To the contents of the Kjeldahl flask, add 30 ml of NaOH (2%) automatically and keep the flask in place. Start the distillation process for 9 minutes. After completion of distillation, take out the conical flask containing the distillate from the unit and titrate the contents against standard  $\text{H}_2\text{SO}_4$  (0.02 N) till the bluish green colour turns light red. (Semi auto Nitrogen analyser, KEL PLUS-Elite EX-VA)

#### **3.4.2.6. Available Phosphorous**

Available Phosphorous was extracted with Bray's P-1 [0.03N  $\text{NH}_4\text{F}$  and 0.025N HCl (pH-2.5)] was shaken with the extractant (Soil: Extractant- 1:10) for 5 minutes where soil pH <6.0 and Olsen's reagent (0.5M  $\text{NaHCO}_3$ ; pH-8.5) where soil >6.0. Soil was shaken with the extractant (Soil: Extractant- 1:20) for 30 min. Phosphorus in the aliquot was by ammonium-molybdate-ascorbic acid method using Spectrophotometer (Model No.:Elico SL 177) at a wave length 720 nm (Page *et al.* 1982).

#### **3.4.2.7. Available K**

Available K was determined by flame photometer after extracting the soil with neutral normal ammonium acetate (Schollenberger and Simon, 1945). Take 5g of soil in a conical flask, add 25 ml of 1N neutral normal ammonium acetate solution and shake for 30 minutes and filter the suspension with filter paper. Feed the solution to the atomizer of the flame photometer and recorded the reading.

**3.4.2.8. Available micronutrients (zinc, manganese, copper and iron)**

Available micro-nutrients and heavy metal were extracted with the help of mixed solution of 0.005 M DTPA, 0.01 M Calcium Chloride and 0.1 M Triethanolamine (TEA) at pH 7.3 (Lindsay and Norvell, 1978). 10 g soil/sludge was taken in 100 mL conical flask and 20 mL of DTPA solution was added to it. It was shaken for 2 hours on a horizontal shaker. Filtrate through Whatman no. 42 filter paper. The concentrations of micronutrient were estimated with the help of Atomic Absorption Spectrophotometer (Mode AAS-4141M) (Lindsay and Norvell, 1978).

**3.4.3. Soil carbon pools****3.4.3.1.  $\text{KMnO}_4$  oxidisable carbon**

$\text{KMnO}_4$  oxidizable carbon (PmOC) was estimated by treating the soil with 33 mM  $\text{KMnO}_4$  (Blair et al. 1995). Samples were shaken for 2 hours and then centrifuged. The absorbance of the supernatant and standards was read on spectrophotometer at 550 nm.

**3.4.3.2. Soil microbial biomass carbon (SMBC)**

Soil microbial biomass was measured by the chloroform fumigation extraction method (Vance *et al.* 1987). Fresh soil samples maintained at 4 °C were taken for the study. Fumigated and unfumigated samples were treated with 0.5 M  $\text{K}_2\text{SO}_4$ . The Carbon in the fumigated and unfumigated extracts was measured and the difference obtained was used to calculate SMBC.

**3.4.3.3. Water soluble carbon (WSC)**

Water soluble carbon determined by Dichromate digestion (Ghosh, 2003). Soil and water ratio (1:2) shaking 30 minutes centrifuge at 5000 rpm for 10 minutes. Extract 10 ml in conical flask; add 0.2N  $\text{K}_2\text{Cr}_2\text{O}_7$  and conc. sulphuric acid, diphenyl amine (DPA) indicator and titration with 0.1N ferrous ammonium sulphate (FAS).

**3.4.3.4. Water soluble carbohydrate (WSCHO)**

Water soluble carbohydrate determined by phenol sulphuric acid method (Dubois *et al.*, 1956). Soil and water ratio (1:10) shaking 16 hours on rotary shaker and centrifuge at 8000 rpm for 10 minutes filter with what man no. 1 filter paper. Collect aliquot and take 2 ml of aliquot in test tube and add 1ml of phenol (5 % aqueous solution). Add 5 ml conc. sulphuric

acid and kept 10 minute for cooling. Vortexes for 30 second and kept in water bath at 25 degree Celsius for 20 minute take reading in spectrophotometer at 490 nm.

### **3.4.3.5. Total organic carbon (TOC)**

Weigh 0.5 g soil in an Erlenmeyer flask. Add 10 ml sulphuric acid and 5 ml phosphoric acid kept in micro-oven at 160°C for 15 minutes. After 20 minutes add 1-2 drop of diphenylamine indicator and titrate with 0.5 M ferrous ammonium sulphate. Trap the evolve carbon oxide after wet oxidation and determine the total organic carbon (Snyder and Trofymow, 1984).

### **3.5 Statistical analysis**

The soil physical, chemical properties and pools of carbon were subjected to analysis of variance. The least significance difference (LSD) test was used to separate significantly differing treatment means after main effects were found significant at  $P < 0.05$ . Moreover, simple correlation analysis was executed with the help Pearson's Correlation Coefficient to reveal the magnitudes and directions of relationships between selected soil fertility parameters and within and among land use types and soil depths.

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## *Results and Discussion*

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### **4.1 Soil Physical Properties**

#### **4.1.1 Texture composition**

Table 2 represents the effect of land use on soil texture location wise in Banka district of Bihar. The soils under study showed % variation in texture composition and textural class of the soils ranging from loamy sand to sandy loam. Sand fraction was found to be maximum in most of the soil samples. Per cent silt and clay content was more in cultivated and orchard land due to transportation of these fractions in lower regions due to heavy rain as well as heavy wind erosion. Sand content in surface soil 69.5 (Simra) to 70.7% (Jhathornath and Poparava) (mean 70.4%) in forest land, 27.1 (Antichak) to 78.7% (Ambedkar Nagar) (mean 53.9 %) in grazing land, 28.7 (Jhathorenath) to 70.7 (Simra) (mean 50.6 %) in cultivated land and 26.1(Antichak) to 80.4 % (Ambedkar Nagar) (mean 63.8 %) in orchard land. In sub-surface soil average % of sand fraction was found 68.8, 52.4, 52.2 and 64 in forest, grazing, cultivated and orchards land respectively. The % of silt fraction in surface soil 20.9 (Simra) to 22.2 (Kaniket) (mean 21.3) in forest land, 12 (Ambedkar Nagar) to 63.3 ( Kaniket) (mean 36) in grazing land, 18 (Simra) to 60.2 (Ambedkar Nagar) (mean 38.5) in cultivated land and 8.1 (Simra) to 63.3 (Antichak) (mean 25.5) in orchard land. In sub-surface soil average % of silt fraction was found 21.8, 36.5, 36.5 and 23.8 in forest, grazing, cultivated and orchard land. Clay % in surface soil varies from 6.8 (Poparava) to 9.6 (Simra) (mean 8.3) in forest land, 5 (Kaniket) to 11.5 (Simra) (mean 10.1) in grazing land, 7.1 (Ambedkar Nagar) to 12.5 (Jhathorenath) (mean 10.9) in cultivated land and 7.7 (Jhathorenath) to 14.7 (Poparava) (mean 10.7) in orchards land whereas sub-surface soil average % of clay fraction was found 9.7, 11.1, 12.1 and 12.2 in forest, grazing, cultivated and orchard land respectively.

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**Table 2: Effect of land use on soil texture (%)**

| Locations  | Jhathornath |      |      | Kaniket |      |      | Antichak |      |      | Simra |      |      | Poparava |      |      | Ambedkar Nagar |      |      | mean |      |      |
|------------|-------------|------|------|---------|------|------|----------|------|------|-------|------|------|----------|------|------|----------------|------|------|------|------|------|
| Treatments | 0-15 cm     |      |      |         |      |      |          |      |      |       |      |      |          |      |      |                |      |      |      |      |      |
|            | sand        | silt | clay | sand    | silt | clay | sand     | silt | clay | sand  | silt | clay | sand     | silt | clay | sand           | silt | clay | sand | silt | clay |
| Forest     | 70.7        | 21.0 | 8.3  | 70.2    | 22.2 | 7.6  | 70.4     | 20.9 | 8.6  | 69.5  | 20.9 | 9.6  | 70.7     | 21.3 | 6.8  | 70.6           | 21.3 | 8.1  | 70.4 | 21.3 | 8.3  |
| Grazing    | 66.8        | 22.3 | 10.9 | 32.2    | 63.3 | 5.0  | 27.1     | 63.6 | 9.3  | 45.9  | 42.6 | 11.5 | 72.6     | 17.3 | 13.4 | 78.7           | 12.0 | 10.6 | 53.9 | 36   | 10.1 |
| Cultivated | 28.7        | 58.8 | 12.5 | 67.9    | 20.5 | 11.7 | 67.5     | 24.3 | 8.2  | 70.7  | 18.0 | 11.3 | 35.7     | 57.2 | 14.3 | 33.1           | 60.2 | 7.1  | 50.6 | 38.5 | 10.9 |
| Orchards   | 72.7        | 19.6 | 7.7  | 57.4    | 32.5 | 10.2 | 26.1     | 63.3 | 10.6 | 71.7  | 8.1  | 9.6  | 74.7     | 10.7 | 14.7 | 80.5           | 8.9  | 11.2 | 63.8 | 25.5 | 10.7 |
| mean       | 56.9        | 32.9 | 10.2 | 55.6    | 35.9 | 8.6  | 35.3     | 55.4 | 9.3  | 57.8  | 28.9 | 10.7 | 61.3     | 29.1 | 13.2 | 62.3           | 28.4 | 8.9  | 54.9 | 35.1 | 10   |
|            | 15-30 cm    |      |      |         |      |      |          |      |      |       |      |      |          |      |      |                |      |      |      |      |      |
| Forest     | 68.3        | 22.7 | 9.0  | 70.4    | 20.5 | 9.1  | 66.4     | 24.2 | 9.4  | 69.1  | 20.2 | 10.7 | 69.1     | 22.5 | 9.6  | 69.4           | 20.4 | 10.2 | 68.5 | 21.8 | 9.7  |
| Grazing    | 63.4        | 26.2 | 10.4 | 30.6    | 62.9 | 6.5  | 30.5     | 56.4 | 13.1 | 51.2  | 40.5 | 8.3  | 69.3     | 17.5 | 8.3  | 69.3           | 15.6 | 13.3 | 52.4 | 36.5 | 11.1 |
| Cultivated | 35.0        | 52.2 | 12.8 | 66.6    | 22.3 | 11.2 | 65.3     | 23.5 | 11.2 | 68.6  | 16.7 | 14.7 | 39.6     | 50.8 | 13.3 | 38.4           | 53.2 | 9.6  | 51.4 | 36.5 | 12.1 |
| Orchards   | 70.3        | 18.0 | 11.7 | 55.3    | 33.9 | 10.8 | 30.3     | 55.8 | 14.0 | 76.9  | 11.1 | 12.3 | 74.4     | 11.7 | 13.8 | 76.5           | 12.1 | 11.1 | 64.0 | 23.8 | 12.2 |
| mean       | 56.3        | 32.2 | 11.5 | 53.7    | 37.0 | 9.3  | 37.6     | 50.5 | 11.9 | 59.4  | 28.8 | 11.5 | 58.3     | 29.4 | 11.8 | 59.7           | 28.4 | 11.7 | 54.2 | 34.4 | 11.4 |

**Table 3 Effect of land use on soil physical parameters**

| Parameters | Bulk density<br>(Mg m <sup>-3</sup> ) |      | MWD of stable<br>Aggregate (mm) |      | Max. water holding capacity<br>(%) |       |       |
|------------|---------------------------------------|------|---------------------------------|------|------------------------------------|-------|-------|
|            | Soil depth<br>(cm)                    | 0-15 | 15-30                           | 0-15 | 15-30                              | 0-15  | 15-30 |
| Land use   |                                       |      |                                 |      |                                    |       |       |
| Forest     |                                       | 1.52 | 1.59                            | 1.98 | 0.81                               | 37.65 | 41.87 |
| Grazing    |                                       | 1.56 | 1.61                            | 1.42 | 0.76                               | 37.12 | 37.10 |
| Cultivated |                                       | 1.59 | 1.65                            | 1.00 | 0.65                               | 41.50 | 40.49 |
| Orchards   |                                       | 1.55 | 1.60                            | 1.81 | 0.77                               | 38.42 | 37.64 |
| LSD (0.05) |                                       | 0.05 | NS                              | 0.16 | 0.10                               | 3.01  | 3.33  |

#### 4.1.2 Bulk density

Table 3 represents the effect of land use on soil bulk density. In surface soil (0-15 cm), the highest bulk density was recorded in cultivated land use (1.59 Mg m<sup>-3</sup>) followed by grazing land (1.56 Mg m<sup>-3</sup>), orchard land (1.55 Mg m<sup>-3</sup>) and the lowest in forest land (1.52 Mg m<sup>-3</sup>) whereas in subsurface soil (15-30 cm), the highest bulk density was observed in cultivated land (1.65 Mg m<sup>-3</sup>) followed by grazing land (1.61 Mg m<sup>-3</sup>), orchard land (1.60 Mg m<sup>-3</sup>) and the lowest in forest land (1.59 Mg m<sup>-3</sup>). Trend of bulk density was similar both in surface and subsurface soil irrespective of land use system. Cultivated soil was found to have higher bulk density than rest land uses due to the higher sand content, low organic matter and destruction of soil aggregates by intensive tillage operation. Similar result was reported by (Sharma *et al.*, 2014; Chauhan *et al.* 2014). According to Chauhan *et al.* (2014) cereal based upland soil has highest bulk density while lowest bulk density was in pasture land. Appendix 1 represents the bulk density of six locations of Banka in surface and subsurface soil. Bulk density of surface soil varied from 1.44 (Ambedkar Nagar) to 1.57 Mg m<sup>-3</sup> (Simra) in forest land, 1.51 (Jhathornath) to 1.57 Mg m<sup>-3</sup> (Antchak and Ambedkar Nagar) in grazing land, 1.58 (Poparava and Ambedkar Nagar) to 1.61 Mg m<sup>-3</sup> (Simra) in cultivated land, 1.49 (Jhathornath) to 1.63 Mg m<sup>-3</sup> (Antichak) in orchards land. Similar trend of bulk density was observed in subsurface soil (Appendix 2). In surface soil BD was positively and highly significant with MWD ( $r=0.44^{**}$ ) grazing land and MWD ( $r=0.60^{**}$ ) in cultivated land. In sub-surface soil

negatively correlated with MWD ( $r=0.79^{**}$ ) in forest and MWHC ( $r=0.83^{**}$ ) in cultivated land whereas positively correlated with MWD ( $r=0.68^{**}$ ) in cultivated land, (Appendix 20).

#### **4.1.3 Mean weight diameter (MWD)**

Table 3 in surface soil, increasing trend of MWD was cultivated soil < Grazing land < Orchard land < Forest land. Similar trend of MWD was recorded in subsurface soil. The highest MWD was recorded in forest land (surface soil-1.98 mm and subsurface soil-0.81 mm) while lowest MWD was observed in cultivated land (surface soil-1.00 mm and subsurface soil-0.65 mm). Similar result was reported by Abad *et al.* (2014) that the cultivated soils were considerably lower in MWD in comparison to forest and pasture land use types. The aggregate stability depends on interaction between primary particles and organic constituents to form stable aggregates, which are influenced by various factors related to soil environmental conditions and management practices. Intensive cultivation and lower organic matter content in cultivated land decrease the aggregate stability. The same finding was supported by Caravaca *et al.* (2004) indicated that aggregate stability of cultivated soil was significantly lower (mean 40%) than that of forest soil (mean 82%). Appendix 2 represents the MWD of six locations of Banka in surface and subsurface soil. In surface soil, MWD was found to be varied from 1.03 (Jhathornath) to 2.70 mm (Ambedkar Nagar) in forest land, 0.69 (Kaniket) to 2.25 mm (Ambedkar Nagar) in grazing land, 0.54 (Jhathornath) to 1.81 mm (Ambedkar Nagar) in cultivated land and 0.71 (Kaniket) to 2.34 mm (Ambedkar Nagar) in orchard land. Similar trend of bulk density was observed in subsurface soil.

#### **4.1.4 Maximum water holding capacity (MWHC)**

Maximum water holding capacity of different land uses in surface and subsurface soil has been shown in Table 3. In surface soil increasing trend of MWHC was grazing land < forest land < orchard land < cultivated soil whereas in subsurface soil trend was grazing land < orchard land < cultivated soil < forest land. In surface soil the highest MWHC was obtained for cultivated soil (41.50 %) while in subsurface soil the highest MWHC was obtained for forest land (41.87 %). This may due to deposition of root residue by the forest. Appendix 3 represents the MWHC of six locations of Banka in surface and subsurface soil. was found to be varied from 33.16 (Kaniket and Antichak) to 42.33 % (Ambedkar Nagar) in forest land, 32.51 (Poparava) to 43.80 % (Ambedkar Nagar) in grazing land, 40.29 (Poparava) to 43.71 % (Jhathornath) in cultivated land and 33.75 (Poparava) to 42.90 % (Jhathornath) in orchard land

whereas in subsurface soil MWHC was found to be varied from 38.41 (Kaniket) to 49.59 % (Jhathorenath) in forest land, 33.20 (Kaniket and Antichak) to 44.12% (Ambedkar Nagar) in grazing land, 36.44 (Jhathornath) to 46.77 % (Poparava) in cultivated land and 34.46 (Simra) to 41.32 % (Jhathornath) in orchard land. In surface soil MWHC was negatively and highly significant with MWD ( $r=0.60^{**}$ ) in orchards land and non-significant with MWD in forest, grazing and cultivated land, (Appendix 20).

#### 4.2 Soil Chemical Parameters

**Table 4: Effect of land use on soil chemical parameters**

| Parameters | pH              |      | EC (dS m <sup>-1</sup> ) |      | S.O.C. (%) |      | CEC (cmol (p+) kg <sup>-1</sup> ) |       |       |
|------------|-----------------|------|--------------------------|------|------------|------|-----------------------------------|-------|-------|
|            | Soil depth (cm) | 0-15 | 15-30                    | 0-15 | 15-30      | 0-15 | 15-30                             | 0-15  | 15-30 |
| Land use   |                 |      |                          |      |            |      |                                   |       |       |
| Forest     |                 | 5.87 | 5.81                     | 0.08 | 0.07       | 0.73 | 0.46                              | 14.07 | 15.79 |
| Grazing    |                 | 5.86 | 5.86                     | 0.07 | 0.06       | 0.45 | 0.33                              | 14.01 | 14.43 |
| Cultivated |                 | 6.20 | 6.35                     | 0.12 | 0.10       | 0.39 | 0.29                              | 14.89 | 17.86 |
| Orchards   |                 | 6.13 | 6.02                     | 0.16 | 0.11       | 0.51 | 0.33                              | 14.74 | 17.62 |
| LSD (0.05) |                 | 0.23 | 0.20                     | 0.04 | 0.03       | 0.09 | 0.07                              | NS    | NS    |

##### 4.2.1 pH

Table 4 represents the effect of land use on soil pH. Most of the soil was slightly acidic to normal in nature. In surface soil, the highest pH was recorded in cultivated land use (6.20) followed by orchard land (6.13), forest land (5.87) and the lowest in grazing land (5.86) whereas in subsurface soil the highest pH was observed in cultivated land (6.35) followed by orchard land (6.02), grazing land (5.86) and the lowest in forest land (5.81). Light textured soil and heavy rainfall during rainy season results in leaching of bases and consequently lowering the pH of forest soil. Continued application of fertilizer, irrigation and other agronomic practices in cultivated soil resulted in higher soil pH in comparison to other land uses. Similar results were reported by Sharma *et al.* (2014) in Himalaya’s foothill. Appendix 4 represents the soil pH of six locations of Banka in surface and subsurface soil. In surface soil,

soil pH for surface soil was found to be varied from 5.61 (Jhathornath) to 6.28 (Poparava) in forest land, 5.44 (Kaniket) to 6.19 (Simra) in grazing land, 5.78 (Poparava) to 7.23 (Jhathornath) in cultivated land and 5.23 (Jhathornath) to 6.61 (Kaniket) in orchard land. pH for subsurface soil was found to be varied from 5.39 (Antichak) to 6.32 (Kaniket) in forest land, 5.59 (Kaniket) to 6.05 (Jhathornath) in grazing land, 5.84 (Kaniket) to 7.21 (Jhathornath) in cultivated land and 5.82 (Simra) to 6.41 (Kaniket) in orchard land. In surface soil pH was positively and highly significant with EC ( $r=0.88^{**}$ ) and OC ( $r=0.70^{**}$ ) in forest land, CEC ( $r=0.67^{**}$ ) and MWD ( $r=0.93^{**}$ ) in grazing land EC ( $r=0.96^{**}$ ) and CEC ( $r=0.79^{**}$ ) in cultivated land and EC ( $r=0.84^{**}$ ) and MWHC ( $r=0.64^{**}$ ) in orchard land. In sub-surface soil negatively correlated with EC ( $r=0.82^{**}$ ) in forest and EC ( $r=0.96^{**}$ ) in orchard land, (Appendix 20).

#### **4.2.2 Electrical conductivity (EC)**

Table 4 represents the effect of land use on soil electrical conductivity (EC). In Surface soil, the highest EC was recorded in orchard land use ( $0.16 \text{ dS m}^{-1}$ ) followed by cultivated land ( $0.11 \text{ dS m}^{-1}$ ), forest land ( $0.08 \text{ dS m}^{-1}$ ) and the lowest in grazing land ( $0.06 \text{ dS m}^{-1}$ ) whereas in subsurface soil similar trends was observed. Light textured soil and heavy rainfall during rainy season results in leaching loss of soluble salts. Appendix 5 represents the soil EC of six locations of Banka in surface and subsurface soil. In surface soil, EC for surface soil was found to be varied from 0.05 (Jhathornath & Antichak) to 0.14 (Ambedkar Nagar) in forest land, 0.04 (Kaniket) to  $0.14 \text{ dS m}^{-1}$  (Ambedkar Nagar) in grazing land, 0.06 (Kaniket) to  $0.21 \text{ dS m}^{-1}$  (Jhathornath) in cultivated land and 0.7 (Jhathornath) to  $0.21 \text{ dS m}^{-1}$  (Kaniket & Simra) in orchard land. EC for sub-surface soil was found to be varied from 0.05 (Jhathornath) to  $0.09 \text{ dS m}^{-1}$  (Kaniket & Poparava) in forest land, 0.04 (Antichak) to  $0.07 \text{ dS m}^{-1}$  (Jhathornath, Simra and Kaniket) in grazing land, 0.05 (Antichak) to  $0.21 \text{ dS m}^{-1}$  (Jhathornath) in cultivated land and 0.05 (Jhathornath) to  $0.17 \text{ dS m}^{-1}$  ( Kaniket & Simra) in orchards land. In surface soil EC was positively and highly significant with OC ( $r=0.84^{**}$ ) and MWD ( $r=0.63^{**}$ ) in forest land, CEC ( $r=0.66^{**}$ ) in grazing land, CEC ( $r=0.67^{**}$ ) in cultivated land and negatively correlated with CEC ( $r=0.79^{**}$ ) in orchard land. In sub-surface soil negatively correlated with OC ( $r=0.69^{**}$ ) and MWHC ( $r=0.66^{**}$ ) in forest, BD ( $r=0.95^{**}$ ) in grazing land, and MWD ( $r=0.63^{**}$ ) in orchard land, (Appendix 20).

#### 4.2.3 Soil Organic carbon (S.O.C.)

Table 4 represents the effect of land use on soil organic carbon. In surface soil, the highest SOC was recorded in forest land use (0.75 %) followed by orchard land (0.51 %), grazing land (0.45 %) and cultivated land (0.39 %) whereas in subsurface soil the highest SOC was observed in forest land (0.46 %) followed by orchard and grazing land (0.33 %) and the lowest in cultivated land (0.29 %). Highest organic carbon content was observed forest soil that may be due to continuous leaf fall and growing of grasses on the surface layer of soil. The continued tillage operation year after year, less use of organic matter and turning over of soil has resulted in decrease of organic carbon content in cultivated soil. Similar results were reported by Ahukaemere *et al.* (2015) in forest, fallow and cultivated land. Appendix 6 represents the soil SOC of six locations of Banka in surface and subsurface soil. In surface soil, SOC for surface soil was found to be varied from 0.58 (Simra) to 0.87 % (Ambedkar Nagar) in forest land, 0.39 (Antichak) to 0.49 % (Ambedkar Nagar) in grazing land, 0.36 (Simra and Ambedkar Nagar) to 0.42 % (Kaniket) in cultivated land and 0.40 (Antichak) to 0.62 % (Ambedkar Nagar) in orchard land. SOC for subsurface soil was found to be varied from 0.38 (Kaniket) to 0.50 % (Simra) in forest land, 0.29 (Poparava) to 0.38 % in (Jhathornath) in grazing land, 0.24 (Poparava) to 0.32 % (Antichak) in cultivated land and 0.29 (Poparava) to 0.38 % (Ambedkar Nagar) in orchard land. In surface soil SOC was negatively and highly significant with BD ( $r=0.61^{**}$ ) in forest land and BD ( $r=0.75^{**}$ ) in cultivated land and CEC( $r=0.59^{**}$ ) in orchard land. In sub-surface soil positively correlated with MWD ( $r=0.63^{**}$ ) in forest land and MWHC ( $r=0.74^{**}$ ) in grazing land whereas negatively correlated with BD ( $r=0.54^{**}$ ) and MWHC ( $r=0.88^{**}$ ) in orchard land (Appendix 20).

#### 4.2.4 Cation exchange capacity

Table 4 represents the effect of land use on cation exchange capacity. In surface soil, the highest CEC was recorded in cultivated land use [14.89 cmol (p+) kg<sup>-1</sup>] followed by orchard land (14.74 [cmol p(+) kg<sup>-1</sup>], forest land [14.07 cmol (p+) kg<sup>-1</sup>] and lowest in grazing land [14.01 cmol (p+) kg<sup>-1</sup>] whereas in subsurface soil similar result was found. Highest cation exchange capacity was observed cultivated soil that may be due to presence of exchangeable cation and clay content. Appendix 7 represents the soil CEC of six locations of Banka in

surface and subsurface soil. In surface soil, CEC for surface soil was found to be varied from 14.11 (Jhathor nath) to 16.13 [cmol (p+) kg<sup>-1</sup>] (Simra) in forest land, 10.51 (Jhathor nath) to 16.71 [cmol (p+) kg<sup>-1</sup>] (Ambedkar Nagar) in grazing land, 10.47 (Jhathor nath) to 16.77 [cmol (p+) kg<sup>-1</sup>] (Simra) in cultivated land and 11.98 (Jhathor nath) to 16.54 [cmol (p+) kg<sup>-1</sup>] (Ambedkar Nagar) in orchard land. SOC for subsurface soil was found to be varied from 14.13 (Jhathor nath) to 17.61[cmol (p+) kg<sup>-1</sup>] (Ambedkar Nagar) in forest land, 12.62 (Jhathor nath) to 17.66 [cmol (p+) kg<sup>-1</sup>]in (Ambedkar Nagar) in grazing land, 14.70 (Jhathor nath) to 19.46 [cmol (p+) kg<sup>-1</sup>] (Simra) in cultivated land and 15.54 (Kaniket) to 20.32 [cmol (p+) kg<sup>-1</sup>] (Simra) in orchard land. In surface soil CEC was positively and highly significant with BD (r=0.86\*\*) and MWD (r=0.62\*\*) in grazing land and MWD (r=0.61\*\*) in orchard land, whereas negatively correlated with MWHC (r=0.70\*\*) in cultivated land and MWHC (r=0.86\*\*) in orchard land. In sub-surface soil positively correlated with MWD (r=0.73\*\*) in forest land and MWD (r=0.65\*\*) in orchard land whereas negatively correlated with BD (r=0.76\*\*) in forest land (Appendix 20).

**Table 5: Effect of land use on available macronutrients**

| Parameters         | Available nitrogen  |       | Available phosphorus |       | Available potassium |       |
|--------------------|---------------------|-------|----------------------|-------|---------------------|-------|
|                    | kg ha <sup>-1</sup> |       |                      |       |                     |       |
| Soil depth<br>(cm) | 0-15                | 15-30 | 0-15                 | 15-30 | 0-15                | 15-30 |
| Land use           |                     |       |                      |       |                     |       |
| Forest             | 313                 | 270   | 21                   | 12    | 262                 | 212   |
| Grazing            | 277                 | 242   | 19                   | 8     | 238                 | 196   |
| Cultivated         | 264                 | 233   | 16                   | 9     | 244                 | 191   |
| Orchards           | 283                 | 260   | 15                   | 11    | 289                 | 202   |
| LSD (0.05)         | 23                  | 16    | 3                    | 2     | 26                  | 26    |

#### 4.2.5 Available Nitrogen

Table 5 represents the effect of land use on available nitrogen. In surface soil, the highest available nitrogen was recorded in forest land use (313 kg N ha<sup>-1</sup>) followed by orchard land (283 kg N ha<sup>-1</sup>), grazing land (277 kg N ha<sup>-1</sup>) and lowest in cultivated land (264 kg N ha<sup>-1</sup>) whereas in subsurface soil the similar trend was observed. Highest available nitrogen content was observed in forest soil that may be due to organic matter while lower in cultivated soil due to leaching losses and less organic matter content. Similar result reported by (Gandhe, 2015) in Indore area. Appendix 8 represents the soil nitrogen of six locations of Banka in surface and subsurface soil. In surface soil, available nitrogen for surface soil was found to be varied from 283.84 (Jhathornath) to 337.11 N kg ha<sup>-1</sup> (Ambedkar Nagar) in forest land, 242.49 (Jhathornath) to 308.31 N kg ha<sup>-1</sup> (Simra) in grazing land, 240.96 (Poparava) to 288.38 N kg ha<sup>-1</sup> (Kaniket) in cultivated land and 252.79 (Poparava) to 304 N kg ha<sup>-1</sup> (Simra) in orchard land. Available nitrogen for subsurface soil was found to be varied from 213.66 (Poparava) to 304.96 N kg ha<sup>-1</sup> (Ambedkar Nagar) in forest land, 200.60 (Poparava) to 269.24 N kg ha<sup>-1</sup> (Simra) in grazing land, 204.44 (Jhathornath) to 247.22 N kg ha<sup>-1</sup> (Antichak) in cultivated land and 202.78 (Poparava) to 295.13 N kg ha<sup>-1</sup> (Antichak) in orchard land.

#### 4.2.6 Available phosphorus

Table 5 represents the effect of land use on available phosphorus. In surface soil, the highest available phosphorus was recorded in forest land use (21 kg ha<sup>-1</sup>) followed by grazing land (19 kg ha<sup>-1</sup>), cultivated land (16 kg ha<sup>-1</sup>) and the lowest in orchards land (15 kg ha<sup>-1</sup>) whereas in subsurface soil the highest available phosphorus was observed in forest land (12 kg ha<sup>-1</sup>) followed by orchard land (11 kg ha<sup>-1</sup>), cultivated land (9 kg ha<sup>-1</sup>) and the lowest grazing land (8 kg ha<sup>-1</sup>) was observed. Highest available phosphorus content was observed in forest soil that may be due to organic matter while lower in cultivated soil due to less organic matter content and low use phosphatic fertilizers. Similar result reported by (Mishra *et al.* 2015) mid central valley at Odisha Zone, India. Appendix 9 represents the soil phosphorus of six locations of Banka in surface and subsurface soil. In surface soil, available phosphorus for surface soil was found to be varied from 6.63 (Kaniket) to 62.91 kg ha<sup>-1</sup> (Jhathornath) in forest land, 58.95 (Jhathornath) to 6.50 kg ha<sup>-1</sup> (Kaniket) in grazing land, 5.88 (Kaniket) to 28.22 kg ha<sup>-1</sup> (Jhathornath) in cultivated land and 8.18 (Antichak) to 21.49 kg ha<sup>-1</sup> (Kaniket) in orchard

land. Available phosphorus for subsurface soil was found to be varied from 4.70 (Antichak) to 33.5 kg ha<sup>-1</sup> (Jhathornath) in forest land, 4.8 (Simra) to 15.46 kg ha<sup>-1</sup> (Jhathornath) in grazing land, 5.27 (Kaniket) to 11.13 kg ha<sup>-1</sup> (Ambedkar Nagar) in cultivated land and 1.93 (Antichak) to 17.68 kg ha<sup>-1</sup> (Kaniket) in orchard land.

#### **4.2.7 Available potassium**

Table 5 represents the effect of land use on available potassium. In surface soil, the highest available potassium was recorded in orchard land (289 kg ha<sup>-1</sup>) followed by forest land use (262 kg ha<sup>-1</sup>), cultivated land (244 kg ha<sup>-1</sup>) and the lowest in grazing land (238 kg ha<sup>-1</sup>) whereas in subsurface soil the highest available phosphorus was observed in forest land (212 kg ha<sup>-1</sup>) followed by orchard land (202 kg ha<sup>-1</sup>), grazing land (196 kg ha<sup>-1</sup>) and the lowest cultivated land (191 kg ha<sup>-1</sup>) was observed. Most of the Indian soils are rich in potassium, due to presence of potassium containing minerals like illite, muscovite, glauconite, biotite, phlogopite, sanidine and orthoclase in Indian soil (Naidu *et al.* 2011). Similar result reported by Gandhe 2015 in garden soils of around Indore (M.P). Appendix 10 represents the soil available potassium of six locations of Banka in surface and subsurface soil. In surface soil, available phosphorus for surface soil was found to be varied from 121.05 (Simra) to 330.38 kg ha<sup>-1</sup> (Ambedkar Nagar) in forest land, 137.11 (Simra) to 344.38 kg ha<sup>-1</sup> (Jhathornath) in grazing land, 129.41 (Kaniket) to 349.57 kg ha<sup>-1</sup> (Jhathornath) in cultivated land and 172.51 (Antichak) to 374.68 kg ha<sup>-1</sup> (Poparava) in orchard land. Available phosphorus for subsurface soil was found to be varied from 159.22 (Simra) to 286.88 kg ha<sup>-1</sup> (Ambedkar Nagar) in forest land, 109.51 (Simra) to 275.57 kg ha<sup>-1</sup> (Jhathornath) in grazing land, 75.96 (Simra) to 281.98 kg ha<sup>-1</sup> (Jhathornath) in cultivated land and 67.01 (Jhathornath) to 325.25 kg ha<sup>-1</sup> (Antichak) in orchard land.

**Table 6: Effect of land use on DTPA extractable micronutrients**

| Parameters        | Manganese              |       | Iron |       | Copper |       | Zinc |       |
|-------------------|------------------------|-------|------|-------|--------|-------|------|-------|
|                   | (mg kg <sup>-1</sup> ) |       |      |       |        |       |      |       |
| Soil depth (cm)   | 0-15                   | 15-30 | 0-15 | 15-30 | 0-15   | 15-30 | 0-15 | 15-30 |
| Land use          |                        |       |      |       |        |       |      |       |
| <b>Forest</b>     | 49                     | 45    | 42   | 32    | 2.87   | 2.21  | 1.72 | 1.80  |
| <b>Grazing</b>    | 41                     | 37    | 41   | 32    | 2.52   | 1.97  | 1.59 | 1.87  |
| <b>Cultivated</b> | 41                     | 38    | 29   | 23    | 2.26   | 1.67  | 1.76 | 1.55  |
| <b>Orchards</b>   | 36                     | 34    | 33   | 27    | 2.48   | 1.96  | 1.59 | 1.74  |
| <b>LSD (0.05)</b> | 2                      | 3     | 2    | 3     | NS     | 0.32  | 0.13 | 0.11  |

#### 4.2.8 Available micronutrients

Table 6 represents the effect of land use on available manganese. In surface soil, the highest available manganese was recorded in forest land (49 mg kg<sup>-1</sup>) followed by grazing and cultivated land (41 mg kg<sup>-1</sup>) and the lowest in orchard land (36 mg kg<sup>-1</sup>) whereas in subsurface soil the highest available manganese was observed in forest land (45 mg kg<sup>-1</sup>) followed by cultivated land (38 mg kg<sup>-1</sup>), grazing land (37 mg kg<sup>-1</sup>) and the lowest in orchard land (34 mg kg<sup>-1</sup>) was observed. The Highest manganese were found in forest land due to organic matter and presence of parent material while lower in cultivated soil due to presence of less organic matter. Appendix 11 represents the soil available manganese of six locations of Banka in surface and sub-surface soil. In surface soil, available manganese for surface soil was found to be varied from 25.78 (Poparava) to 64.93 mg kg<sup>-1</sup> (Antichak) in forest land, 26.05 (Antichak) to 53.12 mg kg<sup>-1</sup> (Kaniket) in grazing land, 23.98 (Jhathor nath) to 70. mg kg<sup>-1</sup> (Poparava ) in cultivated land and 21.70 (Simra) to 47.61 mg kg<sup>-1</sup> (Antichak) in orchard land. Available manganese for sub-surface soil was found to be varied from 35.66 (Poparava) to 58.36 mg kg<sup>-1</sup> (Antichak) in forest land, 20.92 (Antichak) to 47.32 mg kg<sup>-1</sup> (Kaniket) in grazing land, 18.55 (AmbedkarNagar) to 59.69 mg kg<sup>-1</sup> (Antichak) in cultivated land and 15.41 (Simra) to 48.06 mg kg<sup>-1</sup> (Jhathor nath) in orchard land.

Effect of land use on available iron. In surface soil, the highest available iron was recorded in forest land ( $42 \text{ mg kg}^{-1}$ ) followed by grazing land ( $41 \text{ mg kg}^{-1}$ ), orchard land ( $33 \text{ mg kg}^{-1}$ ) and the lowest in cultivated land ( $29 \text{ mg kg}^{-1}$ ) whereas in subsurface soil the highest available iron was observed in forest and grazing land ( $32 \text{ mg kg}^{-1}$ ) followed by orchard land ( $27 \text{ mg kg}^{-1}$ ), and the lowest in cultivated land ( $23 \text{ mg kg}^{-1}$ ) was observed. Appendix 12 represents the soil available manganese of six locations of Banka in surface and sub-surface soil. In surface soil, available iron for surface soil was found to be varied from 33.74 (Kaniket) to 58.51  $\text{mg kg}^{-1}$  (Ambedkar Nagar) in forest land, 26.37 (Antichak) to 52.61  $\text{mg kg}^{-1}$  (Kaniket) in grazing land, 25.39 (Kaniket) to 38.71  $\text{mg kg}^{-1}$  (Jhathornath) in cultivated land and 29.13 (Poparava) to 40.37  $\text{mg kg}^{-1}$  (Jhathornath) in orchard land. Available iron for sub-surface soil was found to be varied from 21.30 (Kaniket) to 43.73  $\text{mg kg}^{-1}$  (Ambedkar Nagar) in forest land, 23.10 (Antichak) to 38.97  $\text{mg kg}^{-1}$  (Poparava) in grazing land, 19.68 (Ambedkar Nagar) to 29.65  $\text{mg kg}^{-1}$  (Jhathornath) in cultivated land and 23.10 (Antichak) to 32.54  $\text{mg kg}^{-1}$  (Jhathornath) in orchard land.

Effect of land use on available copper. In surface soil, the highest available iron was recorded in forest land ( $2.87 \text{ mg kg}^{-1}$ ) followed by grazing land ( $2.52 \text{ mg kg}^{-1}$ ) orchard land  $2.48 \text{ mg kg}^{-1}$  and the lowest in cultivated land ( $2.26 \text{ mg kg}^{-1}$ ) whereas in subsurface soil similar trend was observed. Appendix 13 represents the soil available copper of six locations of Banka in surface and sub-surface soil. In surface soil, available copper was found to be varied from 2.24 (Antichak) to 3.70  $\text{mg kg}^{-1}$  (Ambedkar Nagar) in forest land, 2.19 (Antichak) to 2.71  $\text{mg kg}^{-1}$  (Simira) in grazing land, 1.78 (Antichak) to 2.62  $\text{mg kg}^{-1}$  (Ambedkar Nagar) in cultivated land and 1.90  $\text{mg kg}^{-1}$  (Jhathornath) to 2.95 (Ambedkar Nagar) in orchards land. Available copper for sub-surface soil was found to be varied from 1.74 (Poparava) to 2.73  $\text{mg kg}^{-1}$  (Simra) in forest land, 1.47 (Antichak) to 2.43  $\text{mg kg}^{-1}$  (Simra) in grazing land, 1.23 (Antichak) to 1.97  $\text{mg kg}^{-1}$  (Ambedkar Nagar) in cultivated land and 1.55 (Antichak) to 2.43  $\text{mg kg}^{-1}$  (Simra) in orchard land.

Effect of land use on available zinc. In surface soil, the highest available zinc was recorded in cultivated land ( $1.76 \text{ mg kg}^{-1}$ ) followed by forest land ( $1.72 \text{ mg kg}^{-1}$ ) and the lowest in grazing and orchard land ( $1.59 \text{ mg kg}^{-1}$ ). Whereas in sub-surface soil the highest available zinc was observed in grazing land ( $1.87 \text{ mg kg}^{-1}$ ) followed by forest land ( $1.80 \text{ mg kg}^{-1}$ ), orchard land ( $1.74 \text{ mg kg}^{-1}$ ) and the lowest in cultivated land ( $1.55 \text{ mg kg}^{-1}$ ) was

observed. Appendix 14 represents the soil available zinc of six locations of Banka in surface and sub-surface soil. In surface soil, available zinc was found to be varied from 1.17 (Kaniket) to 2.43 mgkg<sup>-1</sup> (Jhathornath) in forest land, 1.17 (Simira) to 1.82 mgkg<sup>-1</sup> (Jhathornath) in grazing land, 1.19 (Simira) to 3.57 mg kg<sup>-1</sup> (Kaniket) in cultivated land and 1.11 (Ambedkar Nagar) to 2.54 mg kg<sup>-1</sup> (Simira) in orchards land. Available zinc for sub-surface soil was found to be varied from 1.15 (Kaniket) to 3.24 mg kg<sup>-1</sup> (Ambedkar Nagar) in forest land, 1.27 (Antichak) to 2.99 mgkg<sup>-1</sup> (Ambedkar Nagar) in grazing land, 0.95 (Ambedkar Nagar) to 2.66 mg kg<sup>-1</sup> (Kaniket) in cultivated land and 1.01 (Antichak) to 2.71 mg kg<sup>-1</sup> (Ambedkar Nagar) in orchard land. Yitbarek *et al.* (2013) reported that the available micronutrients (Fe, Mn, Zn and Cu) were declined by 6.79, 29.47, 40.05 and 53.92%, respectively, in cultivated land in comparison with the forest land.

### 4.3 Soil Active or labile carbon pools

**Table-7: Effect of land use on active carbon pools (mg kg<sup>-1</sup>) of the soils**

| Parameters        | Potassium permanganate oxidizable carbon |       | Water Soluble Carbon |       | Water Soluble Carbohydrate |       | Soil microbial biomass carbon |       |
|-------------------|--|-------|----------------------|-------|----------------------------|-------|-------------------------------|-------|
|                   | (mg kg <sup>-1</sup> )                   |       |                      |       |                            |       |                               |       |
| Soil depths (cm)  | 0-15                                     | 15-30 | 0-15                 | 15-30 | 0-15                       | 15-30 | 0-15                          | 15-30 |
| <b>Forest</b>     | 552                                      | 397   | 182                  | 104   | 414                        | 160   | 815                           | 415   |
| <b>Grazing</b>    | 514                                      | 377   | 122                  | 53    | 370                        | 151   | 562                           | 342   |
| <b>Cultivated</b> | 458                                      | 364   | 87                   | 41    | 348                        | 145   | 628                           | 360   |
| <b>Orchards</b>   | 525                                      | 383   | 149                  | 70    | 402                        | 155   | 715                           | 398   |
| <b>LSD (0.05)</b> | 43                                       | NS    | 17                   | 12    | 22                         | 12    | 69                            | 55    |

#### 4.3.1. Potassium permanganate oxidisable carbon (PmOC)

Table 7 represents the effect of land use on Potassium permanganate oxidisable carbon (PmOC). In surface soil, the highest PmOC was recorded in forest land (552 mg kg<sup>-1</sup>) followed by orchard land (525 mg kg<sup>-1</sup>), grazing land (514 mg kg<sup>-1</sup>) and the lowest in cultivated land (458 mg kg<sup>-1</sup>) whereas in subsurface soil the highest PmOC was observed in forest land (397 mg kg<sup>-1</sup>), followed by orchard land (383 mg kg<sup>-1</sup>), grazing land (377 mg kg<sup>-1</sup>) and the lowest in cultivated land (364 mg kg<sup>-1</sup>) was observed. Forest soil was highest PmOC due to presence of organic matter. Similar result was reported by (Aumtong *et al.*, 2009; Kaur *et al.* 2000) in forests, plantation and farm soils. Appendix 15 represents the soil available manganese of six locations of Banka in surface and sub-surface soil. In surface soil, PmOC for surface soil was found to be varied from 353 (Kaniket) to 717 mg kg<sup>-1</sup> (Antichak) in forest land, 340 (Jhathornath) to 712 mg kg<sup>-1</sup> (Ambedkar Nagar) in grazing land, 375 (Simra) to 646 mg kg<sup>-1</sup> (Kaniket) in cultivated land and 462 (Poparava) to 580 mg kg<sup>-1</sup> (Antichak) in orchard land. PmOC for sub-surface soil was found to be varied from 311(Kaniket) to 506 mg kg<sup>-1</sup> (Antichak) in forest land, 325 (Jhathornath) to 471 mg kg<sup>-1</sup> (Antichak) in grazing land, 310 (Jhathornath) to 440 mg kg<sup>-1</sup> (Antichak) in cultivated land and 259 (Jhathornath) to 488 mg kg<sup>-1</sup> (Kaniket) in orchard land. In surface soil, PmOC was negatively and highly significant with WSCHO ( $r=0.65^{**}$ ) in forest land and WSCHO ( $r=64^{**}$ ) in cultivated land whereas, non-significant with WSC and WSCHO in orchard, grazing and cultivated land, (Appendix 21).

#### 4.3.2. Water soluble carbon (WSC)

Table 7 represents the effect of land use on water soluble carbon (WSC). In surface soil, the highest WSC was recorded in forest land (182 mg kg<sup>-1</sup>) followed by orchard land (149 mg kg<sup>-1</sup>), grazing land (122 mg kg<sup>-1</sup>) and lowest in cultivated land (87 mg kg<sup>-1</sup>). Whereas, in sub-surface soil the similar result was found. Similar result was reported by Sharma *et al.* (2014) in the foothill Himalayas. Appendix 16 represents the soil WSC of six locations of Banka in surface and sub-surface soil. In surface soil, WSC was found to be varied from 94 (Ambedkar Nagar) to 238 mg kg<sup>-1</sup> (Simira) in forest land, 71 (Ambedkar Nagar) to 170.0 mg kg<sup>-1</sup> (Jhathornath) in grazing land, 62. (Ambedkar Nagar) to 145 mg kg<sup>-1</sup> (Jhathornath) in cultivated land and 72 (Ambedkar Nagar) to 204 mg kg<sup>-1</sup> (Jhathornath) in orchards land.

Water soluble carbon for sub-surface soil was found to be varied from 46 (Ambedkar Nagar) to 136 mg kg<sup>-1</sup> (Jhathornath) in forest land, 20 (Ambedkar Nagar) to 68 mg kg<sup>-1</sup> (Jhathornath) in grazing land, 19 (Ambedkar Nagar) to 59 mg kg<sup>-1</sup> (Jhathornath) in cultivated land and 23 (Ambedkar Nagar) to 96 mg kg<sup>-1</sup> (Simra) in orchard land.

#### **4.3.3. Water soluble carbohydrate (WSCHO)**

Table 7 represents the effect of land use on water soluble carbohydrate (WSCHO). In surface soil, the highest WSCHO was recorded in forest land (414 mg kg<sup>-1</sup>) followed by orchard land (402 mg kg<sup>-1</sup>), grazing land (370 mg kg<sup>-1</sup>) and the lowest in cultivated land (348 mg kg<sup>-1</sup>), Similar result was found in sub-surface soil. This could be due to a greater return of plant residues (especially leaf residues) and less soil disturbance in the forest which led to a greater rate of SOM in forest lands similar result was reported by Fallahzade and Hajabbasi. (2012) in central Zagros Mountains. Appendix 17 represents the soil WSCHO of six locations of Banka in surface and sub-surface soil. In surface soil, WSCHO was found to be varied from 220 (Simira) to 604 mg kg<sup>-1</sup> (Kaniket) in forest land, 128. (Simira) to 479 mg kg<sup>-1</sup> (Jathornath) in grazing land, 131 (Jathornath) to 659 mg kg<sup>-1</sup> (Simira) in cultivated and 270 (Simira) to 532 mg kg<sup>-1</sup> (Kaniket) in orchard land. Water soluble carbohydrate for sub-surface soil was found to be varied from 120 (Ambedkar Nagar) to 233 mg kg<sup>-1</sup> (Kaniket) in forest land, 70 (Ambedkar Nagar) to 231 mg kg<sup>-1</sup> (Kaniket) in grazing land, 62 (Jhathornath) to 229 mg kg<sup>-1</sup> (Antichak) in cultivated land and 121 (Antichak) to 233 mg kg<sup>-1</sup> (Poparava) in orchard land. In sub- surface soil WSCHO was positively and highly significant with WSC (r=0.73\*\*) in orchard whereas non-significant with WSC in forest, grazing and cultivated land, (Appendix 21).

#### **4.3.4. Soil Microbial biomass carbon (SMBC)**

Table 7 represents the effect of land use on Soil microbial biomass (SMBC). In surface soil, the highest SMBC was recorded in forest land (815 mg kg<sup>-1</sup>) followed by orchard land (715 mg kg<sup>-1</sup>), cultivated land (628 mg kg<sup>-1</sup>) and lowest in grazing land (562 mg kg<sup>-1</sup>). Whereas in sub-surface soil the similar result was found. Appendix 18 represents the soil SMBC of six locations of Banka in surface and sub-surface soils. In surface soil, SMBC was found to be varied from 300 (Ambedkar Nagar) to 1060 mg kg<sup>-1</sup> (Jhathorenath) in forest land, 220 (Simira) to 920 mg kg<sup>-1</sup> (Poparava) in grazing land, 300 (Jhathornath) to 1540 mg kg<sup>-1</sup> (Simira) in cultivated land and 370 (Antichak) to 1180 mg kg<sup>-1</sup> (Kaniket) in orchards land. SMBC for sub-surface soil was found to be varied from 210 (Antichak) to 640 mg kg<sup>-1</sup> (Simira) in forest

land, 80 (Jhathornath) to 680 mgkg<sup>-1</sup> (Poparava) in grazing land, 90 (Jhathornath) to 900 mg kg<sup>-1</sup> (Simra) in cultivated land and 270 (Antichak) to 578 mg kg<sup>-1</sup> (Poparava) in orchard land. Low concentration of MBC and PmOC in agricultural land use systems can be attributed to tillage practices. Cultivation period have a negative effect on labile carbon (Shrestha et al., 2006). In surface soil MBC was positively and highly significant with WSCHO (r=0.95\*\*) in forest land, WSCHO (r=0.97\*\*) in grazing land, WSCHO (r=0.99\*\*) in cultivated land and WSCHO (r=0.90\*\*) in orchards land whereas negatively and highly significant with PmOC (r=0.74\*\*) in forest, PmOC (r=69\*\*) in cultivated land and PmOC (r=0.71\*\*). In sub surface soils, positively and highly significant with WSC (r=65\*\*) and WSCHO (r=77\*\*) in forest land, WSCHO (r=96\*\*) in grazing land, WSCHO (r=0.98\*\*) in cultivated land and WSCHO (r=0.96\*\*) in orchard, (Appendix 21).

#### **4.3.5. Total organic carbon (TOC)**

Appendix 19 represents the effect of land use on Total organic carbon (TOC). In surface soil, the highest TOC was recorded in forest land (1.63 %) followed by orchard land (1.42 %), grazing land (1.40 %) and lowest in cultivated land (1.36 %), Similar result was found in sub-surface soil. whereas in subsurface soil the highest TOC was observed in forest land (1.01 %), followed by grazing land (0.86 %), orchard land (0.87 %) and the lowest in cultivated land (0.81 %) was observed. Appendix 19 represents the soil TOC of six locations of Banka in surface and sub-surface soil. In surface soil, TOC was found to be varied from 1.15 (Poparava) to 2.04 % (Ambedkar Nagar) in forest land , 0.66 (Simira) to 1.79 % (Ambedkar Nagar) in grazing land, 0.76 (Simra) to 1.91 % (Kaniket) in cultivated and 0.90 (Simira) to 2.14 % (Kaniket) in orchard land. TOC for sub-surface soil was found to be varied from 0.67 (Jhathornat) to 1.55 % (Antichak) in forest land, 0.56 (Simra) to 1.38 % ( Jhathornath) in grazing land, 0.63 (Antichak) to 1.20 % (Jhathornath) in cultivated land and 0.71 (Jhathornath) to 1.31 % (Kaniket) in orchard land. In surface soil TOC was positively and highly significant with WSCHO (r=0.81\*\*) and MBC (r=0.72\*\*) in grazing land, WSCHO (r=0.75\*\*) and MBC (r=0.78\*\*) in orchards land whereas negatively and highly significant WSCHO (r=0.58\*\*) and MBC (r=0.62\*\*) in cultivated land. In sub surface soils of forest land TOC was positively and highly significant related with MBC (r=58\*\*), (Appendix 21).

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## *Summary and Conclusion*

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The study was conducted in Banka district which is located in South Bihar Alluvial plain zone (i.e. Agro climatic Zone IIIA of Bihar). The agricultural productivity of Banka district is low due to undulating terrain and lack of irrigation facilities. The triplicate soil samples were collected from six locations across four land use systems viz. forest, grazing, cultivated and orchards lands at two soil depths (0-15 cm and 15-30 cm). The collected soil samples were air dried ground and processed to analyze various soil properties except bulk density, for which soil samples were collected from each sites using a core sampler.

Clay content was found higher in cultivated land comparison to forest, grazing and orchard land. In surface soil, bulk density of cultivated land was found highest in cultivated land and lowest in forest land in surface and sub-surface soil aggregate stability (MWD) was found highest in forest land followed by orchards, grazing and cultivated land. Surface soil MWHC was found maximum in cultivated land and minimum in grazing land whereas in sub-surface highest in forest followed by cultivated, orchard and lowest in grazing land. The result clearly indicated that change in land use system affect soil fertility status.

pH of soil slightly acidic to neutral. In surface soil cultivated land highest pH followed by orchard, forest and lowest in grazing land whereas sub-surface highest in cultivated land and lowest in forest land. EC of the soil was non saline in nature. In surface and sub-surface soil organic carbon (SOC) highest in forest land followed by orchard, grazing and lowest in cultivated land. In surface soil CEC was found increasing order forest < grazing < orchard < cultivated land. Similar trend was observed in sub-surface soils. Available Nitrogen, phosphorus and potassium were found higher in forest land in surface soil whereas similar trend was observed in sub-surface soil. Surface and sub-surface DTPA extractable micronutrient ( Mn, Fe, and Cu) was found highest in forest land and lowest in cultivated land. In surface soil Zn was found inverse i.e. highest in cultivated land and lowest in grazing and orchards land whereas in sub-surface soil highest in grazing followed by forest, orchards and cultivated land.

## Summary and Conclusion

Among the different active carbon pools, the highest water soluble carbon (WSC), water soluble carbohydrate (WSCHO), Potassium permanganate oxidizable (PmOC) and soil microbial biomass carbon (SMBC) was recorded in forest soil followed by orchards, grazing and cultivated land in surface soil. Similar trend was observed in subsurface soil. The total organic carbon (TOC) was highest in forest land while lowest in cultivated soil.

Thus, it may be concluded that management practices such as grazing, deforestation, continuous cultivation turn down the soil fertility as compared to existing natural land use system like forest land. Conversion in land use from forest land to cultivated land can have detrimental effect on soil carbon pool. Agricultural disturbances, like tillage, removal of crop residue and enhanced soil erosion could be the major cause of carbon losses from the soil.

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Appendix 1: Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on bulk density (Mg m<sup>-3</sup>)

| Locations<br>Treatments | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean |
|-------------------------|-------------|---------|----------|-------|----------|----------------|------|
|                         | 0-15 cm     |         |          |       |          |                |      |
| Forest                  | 1.46        | 1.55    | 1.56     | 1.57  | 1.55     | 1.44           | 1.52 |
| Grazing                 | 1.51        | 1.53    | 1.57     | 1.63  | 1.54     | 1.57           | 1.56 |
| Cultivated              | 1.59        | 1.60    | 1.59     | 1.61  | 1.58     | 1.58           | 1.59 |
| Orchard                 | 1.49        | 1.50    | 1.63     | 1.60  | 1.51     | 1.54           | 1.55 |
| Mean                    | 1.51        | 1.54    | 1.59     | 1.60  | 1.54     | 1.53           | 1.55 |
| SEm(±)                  | 0.02        | 0.02    | 0.03     | 0.02  | 0.01     | 0.02           |      |
| LSD (0.05)              | 0.07        | NS      | NS       | 0.05  | NS       | 0.06           |      |
| 15-30 cm                |             |         |          |       |          |                |      |
| Forest                  | 1.62        | 1.59    | 1.65     | 1.61  | 1.59     | 1.47           | 1.59 |
| Grazing                 | 1.57        | 1.59    | 1.69     | 1.60  | 1.61     | 1.61           | 1.61 |
| Cultivated              | 1.64        | 1.62    | 1.68     | 1.65  | 1.71     | 1.59           | 1.65 |
| Orchard                 | 1.59        | 1.61    | 1.66     | 1.62  | 1.55     | 1.56           | 1.60 |
| Mean                    | 1.60        | 1.60    | 1.67     | 1.62  | 1.62     | 1.56           | 1.61 |
| SEm(±)                  | 0.02        | 0.02    | 0.01     | 0.02  | 0.02     | 0.02           |      |
| LSD (0.05)              | NS          | NS      | NS       | NS    | 0.07     | 0.07           |      |

Appendix 2 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on mean weight diameter (mm)

| Locations<br>Treatments | Locations   |         |          |       |          |                | Mean |
|-------------------------|-------------|---------|----------|-------|----------|----------------|------|
|                         | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar |      |
| 0-15 cm                 |             |         |          |       |          |                |      |
| Forest                  | 1.03        | 2.61    | 1.18     | 2.29  | 2.09     | 2.70           | 1.98 |
| Grazing                 | 0.97        | 0.69    | 1.27     | 2.21  | 1.14     | 2.25           | 1.42 |
| Cultivated              | 0.54        | 0.68    | 0.83     | 1.03  | 1.10     | 1.81           | 1.00 |
| Orchard                 | 1.89        | 0.71    | 2.16     | 2.28  | 1.49     | 2.34           | 1.81 |
| Mean                    | 1.11        | 1.17    | 1.36     | 1.95  | 1.45     | 2.27           | 1.55 |
| SEm(±)                  | 0.22        | 0.10    | 0.12     | 0.10  | 0.05     | 0.12           |      |
| LSD (0.05)              | 0.72        | 0.32    | 0.38     | 0.32  | 0.17     | 0.40           |      |
| 15-30 cm                |             |         |          |       |          |                |      |
| Forest                  | 0.69        | 0.55    | 0.84     | 0.72  | 0.72     | 1.35           | 0.81 |
| Grazing                 | 0.38        | 0.49    | 1.03     | 0.87  | 0.69     | 1.07           | 0.76 |
| Cultivated              | 0.32        | 0.46    | 0.73     | 0.71  | 0.68     | 1.01           | 0.65 |
| Orchard                 | 0.62        | 0.53    | 0.77     | 0.82  | 0.71     | 1.14           | 0.77 |
| Mean                    | 0.50        | 0.51    | 0.84     | 0.78  | 0.70     | 1.14           | 0.75 |
| SEm(±)                  | 0.03        | 0.03    | 0.09     | 0.11  | 0.02     | 0.05           |      |
| LSD (0.05)              | 0.09        | NS      | NS       | NS    | NS       | 0.15           |      |

Appendix 3 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on maximum water holding capacity (%)

| Treatments | Locations | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean  |
|------------|-----------|-------------|---------|----------|-------|----------|----------------|-------|
|            |           | 0-15 cm     |         |          |       |          |                |       |
| Forest     |           | 37.60       | 33.16   | 33.16    | 42.14 | 37.49    | 42.33          | 37.65 |
| Grazing    |           | 43.80       | 35.71   | 35.71    | 34.07 | 32.51    | 40.94          | 37.12 |
| Cultivated |           | 43.71       | 41.71   | 41.71    | 40.55 | 40.29    | 41.01          | 41.50 |
| Orchard    |           | 42.90       | 37.89   | 37.89    | 39.26 | 33.75    | 38.83          | 38.42 |
| Mean       |           | 42.00       | 37.12   | 37.12    | 39.01 | 36.01    | 40.78          | 38.67 |
| SEm(±)     |           | 4.69        | 2.56    | 2.56     | 3.27  | 2.82     | 1.68           |       |
| LSD (0.05) |           | NS          | NS      | NS       | NS    | NS       | NS             |       |
|            |           | 15-30 cm    |         |          |       |          |                |       |
| Forest     |           | 49.59       | 38.41   | 38.41    | 42.91 | 39.49    | 42.42          | 41.87 |
| Grazing    |           | 41.26       | 33.30   | 33.30    | 36.69 | 33.91    | 44.12          | 37.10 |
| Cultivated |           | 43.19       | 36.44   | 36.64    | 40.84 | 46.77    | 39.05          | 40.49 |
| Orchard    |           | 41.32       | 34.60   | 34.60    | 34.46 | 40.02    | 40.81          | 37.64 |
| Mean       |           | 43.84       | 35.69   | 35.74    | 38.72 | 40.05    | 41.60          | 39.27 |
| SEm(±)     |           | 3.80        | 1.74    | 1.79     | 1.45  | 3.02     | 1.38           |       |
| LSD (0.05) |           | NS          | NS      | NS       | 4.73  | NS       | NS             |       |

Appendix 4 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on soil pH

| Locations<br>Treatments | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean |
|-------------------------|-------------|---------|----------|-------|----------|----------------|------|
| 0-15 cm                 |             |         |          |       |          |                |      |
| Forest                  | 5.61        | 5.84    | 5.70     | 5.74  | 6.28     | 6.04           | 5.87 |
| Grazing                 | 5.67        | 5.44    | 5.88     | 6.19  | 5.87     | 6.09           | 5.86 |
| Cultivated              | 7.23        | 5.67    | 5.80     | 6.05  | 5.78     | 6.69           | 6.20 |
| Orchards                | 5.23        | 6.61    | 5.81     | 6.54  | 6.34     | 6.25           | 6.13 |
| Mean                    | 5.94        | 5.89    | 5.80     | 6.13  | 6.07     | 6.27           | 6.02 |
| SEm(±)                  | 0.15        | 0.30    | 0.16     | 0.28  | 0.22     | 0.05           |      |
| LSD (0.05)              | 0.49        | NS      | NS       | NS    | NS       | 0.18           |      |
| 15-30 cm                |             |         |          |       |          |                |      |
| Forest                  | 5.54        | 6.32    | 5.39     | 5.55  | 6.13     | 5.95           | 5.81 |
| Grazing                 | 6.05        | 5.59    | 5.97     | 5.82  | 5.99     | 5.75           | 5.86 |
| Cultivated              | 7.21        | 5.84    | 6.06     | 6.65  | 6.14     | 6.18           | 6.35 |
| Orchards                | 5.84        | 6.41    | 6.04     | 5.82  | 6.10     | 5.89           | 6.02 |
| Mean                    | 6.16        | 6.04    | 5.87     | 5.96  | 6.09     | 5.96           | 6.01 |
| SEm(±)                  | 0.21        | 0.19    | 0.22     | 0.22  | 0.18     | 0.07           |      |
| LSD (0.05)              | 0.7         | NS      | NS       | 0.73  | NS       | 0.24           |      |

Appendix 5: Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on soil EC ( $\text{dS m}^{-1}$ )

| Locations<br>Treatments | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean |
|-------------------------|-------------|---------|----------|-------|----------|----------------|------|
| 0-15 cm                 |             |         |          |       |          |                |      |
| Forest                  | 0.05        | 0.07    | 0.05     | 0.06  | 0.12     | 0.14           | 0.08 |
| Grazing                 | 0.06        | 0.04    | 0.05     | 0.05  | 0.09     | 0.14           | 0.07 |
| Cultivated              | 0.21        | 0.06    | 0.08     | 0.09  | 0.14     | 0.13           | 0.12 |
| Orchard                 | 0.07        | 0.21    | 0.14     | 0.21  | 0.15     | 0.17           | 0.16 |
| Mean                    | 0.10        | 0.10    | 0.08     | 0.10  | 0.13     | 0.15           | 0.11 |
| SEm( $\pm$ )            | 0.01        | 0.03    | 0.03     | 0.03  | 0.03     | 0.01           |      |
| LSD (0.05)              | NS          | 0.11    | NS       | 0.11  | NS       | NS             |      |
| LSD (0.01)              | 0.04        | NS      | NS       | NS    | NS       | NS             |      |
| 15-30 cm                |             |         |          |       |          |                |      |
| Forest                  | 0.05        | 0.09    | 0.06     | 0.08  | 0.09     | 0.07           | 0.07 |
| Grazing                 | 0.07        | 0.07    | 0.04     | 0.07  | 0.07     | 0.06           | 0.06 |
| Cultivated              | 0.21        | 0.06    | 0.05     | 0.13  | 0.07     | 0.06           | 0.10 |
| Orchard                 | 0.05        | 0.17    | 0.07     | 0.17  | 0.15     | 0.07           | 0.11 |
| Mean                    | 0.10        | 0.10    | 0.05     | 0.11  | 0.09     | 0.07           | 0.09 |
| SEm( $\pm$ )            | 0.02        | 0.02    | 0.01     | 0.01  | 0.03     | 0.01           |      |
| LSD (0.05)              | 0.06        | 0.05    | NS       | 0.05  | NS       | NS             |      |

Appendix 6 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on soil organic carbon (%)

| Locations<br>Treatments | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean |
|-------------------------|-------------|---------|----------|-------|----------|----------------|------|
| 0-15 cm                 |             |         |          |       |          |                |      |
| Forest                  | 0.77        | 0.74    | 0.59     | 0.58  | 0.85     | 0.87           | 0.73 |
| Grazing                 | 0.47        | 0.47    | 0.39     | 0.46  | 0.43     | 0.49           | 0.45 |
| Cultivated              | 0.41        | 0.42    | 0.39     | 0.36  | 0.38     | 0.36           | 0.39 |
| Orchard                 | 0.60        | 0.50    | 0.40     | 0.47  | 0.45     | 0.63           | 0.51 |
| Mean                    | 0.56        | 0.53    | 0.44     | 0.47  | 0.53     | 0.59           | 0.52 |
| SEm(±)                  | 0.02        | 0.05    | 0.04     | 0.04  | 0.03     | 0.04           |      |
| LSD (0.05)              | 0.07        | 0.16    | 0.14     | 0.15  | 0.09     | 0.13           |      |
| 15-30 cm                |             |         |          |       |          |                |      |
| Forest                  | 0.49        | 0.38    | 0.48     | 0.50  | 0.41     | 0.48           | 0.46 |
| Grazing                 | 0.38        | 0.32    | 0.33     | 0.3   | 0.29     | 0.37           | 0.33 |
| Cultivated              | 0.30        | 0.30    | 0.32     | 0.26  | 0.24     | 0.31           | 0.29 |
| Orchard                 | 0.34        | 0.33    | 0.35     | 0.31  | 0.29     | 0.38           | 0.33 |
| Mean                    | 0.38        | 0.33    | 0.37     | 0.34  | 0.31     | 0.38           | 0.35 |
| SEm(±)                  | 0.01        | 0.02    | 0.03     | 0.03  | 0.02     | 0.02           |      |
| LSD (0.05)              | NS          | NS      | 0.10     | 0.11  | 0.07     | 0.07           |      |

Appendix 7: Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on cation exchange capacity [cmol (p+) kg<sup>-1</sup>]

| Treatments | Locations | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean  |
|------------|-----------|-------------|---------|----------|-------|----------|----------------|-------|
| 0-15 cm    |           |             |         |          |       |          |                |       |
| Forest     |           | 14.11       | 14.91   | 14.21    | 16.13 | 14.87    | 14.47          | 14.78 |
| Grazing    |           | 10.51       | 12.35   | 14.94    | 14.15 | 15.42    | 16.71          | 14.01 |
| Cultivated |           | 10.47       | 14.71   | 16.03    | 16.77 | 15.01    | 16.36          | 14.89 |
| Orchard    |           | 11.98       | 14.63   | 13.65    | 15.38 | 16.27    | 16.54          | 14.74 |
| Mean       |           | 11.77       | 14.15   | 14.71    | 15.61 | 15.39    | 16.02          | 14.61 |
| SEm(±)     |           | 1.36        | 1.31    | 1.62     | 2.18  | 2.10     | 2.95           |       |
| LSD (0.05) |           | NS          | NS      | NS       | NS    | NS       | NS             |       |
| 15-30 cm   |           |             |         |          |       |          |                |       |
| Forest     |           | 14.13       | 15.28   | 15.59    | 15.35 | 16.77    | 17.61          | 15.79 |
| Grazing    |           | 12.62       | 14.66   | 13.25    | 14.42 | 14.35    | 17.27          | 14.43 |
| Cultivated |           | 14.70       | 15.39   | 15.94    | 19.46 | 16.40    | 17.66          | 16.59 |
| Orchard    |           | 15.60       | 15.54   | 15.03    | 20.32 | 16.89    | 16.39          | 16.63 |
| Mean       |           | 14.26       | 15.22   | 14.95    | 17.39 | 16.10    | 17.23          | 15.86 |
| SEm(±)     |           | 2.31        | 1.02    | 2.53     | 2.42  | 2.57     | 3.13           |       |
| LSD (0.05) |           | NS          | NS      | NS       | NS    | NS       | NS             |       |

Appendix 8: Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on available nitrogen ( N kg ha<sup>-1</sup>)

| Locations<br>Treatments | Jhathornath | Kaniket | Antichak | Simra  | Poparava | Ambedkar Nagar | Mean   |
|-------------------------|-------------|---------|----------|--------|----------|----------------|--------|
| 0-15cm                  |             |         |          |        |          |                |        |
| Forest                  | 283.84      | 307.54  | 326.89   | 335.45 | 284.64   | 337.11         | 312.58 |
| Grazing                 | 242.49      | 287.29  | 283.10   | 308.21 | 245.29   | 298.37         | 277.46 |
| Cultivated              | 243.56      | 288.38  | 285.33   | 268.01 | 240.96   | 259.93         | 264.36 |
| Orchard                 | 275.41      | 303.48  | 274.90   | 307.71 | 240.29   | 297.30         | 283.18 |
| Mean                    | 261.33      | 296.67  | 292.56   | 304.85 | 252.79   | 298.18         | 284.40 |
| SEm(±)                  | 6.03        | 3.62    | 5.25     | 7.69   | 6.98     | 4.20           |        |
| LSD (0.05)              | 19.66       | 11.81   | 17.11    | 25.08  | 22.76    | 13.69          |        |
| 15-30 cm                |             |         |          |        |          |                |        |
| Forest                  | 233.91      | 271.28  | 301.05   | 293.88 | 213.66   | 304.96         | 269.79 |
| Grazing                 | 216.99      | 260.31  | 246.85   | 269.24 | 200.60   | 260.34         | 242.39 |
| Cultivated              | 204.44      | 238.33  | 247.22   | 244.19 | 226.67   | 236.68         | 232.92 |
| Orchard                 | 229.51      | 265.01  | 295.13   | 283.21 | 202.78   | 285.66         | 260.22 |
| Mean                    | 221.21      | 258.73  | 272.56   | 272.63 | 210.93   | 271.91         | 251.33 |
| SEm(±)                  | 3.97        | 5.67    | 6.86     | 6.61   | 4.27     | 7.89           |        |
| LSD (0.05)              | 12.94       | 18.48   | 22.38    | 21.56  | 13.93    | 25.73          |        |

Appendix 9 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on available phosphorus ( $P_2O_5$  kg ha<sup>-1</sup>)

| Locations<br>Treatments | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean  |
|-------------------------|-------------|---------|----------|-------|----------|----------------|-------|
| 0-15 cm                 |             |         |          |       |          |                |       |
| Forest                  | 62.91       | 6.63    | 15.91    | 10.83 | 18.31    | 11.07          | 20.94 |
| Grazing                 | 58.95       | 6.50    | 11.48    | 15.98 | 9.84     | 13.48          | 19.37 |
| Cultivated              | 28.22       | 5.88    | 11.28    | 11.79 | 14.43    | 24.73          | 16.06 |
| Orchard                 | 16.57       | 21.49   | 8.18     | 8.49  | 14.06    | 21.34          | 15.02 |
| Mean                    | 41.66       | 10.13   | 11.71    | 11.77 | 14.16    | 17.65          | 17.85 |
| SEm(±)                  | 4.78        | 1.17    | 1.31     | 1.20  | 2.58     | 1.31           |       |
| LSD (0.05)              | 15.58       | 3.81    | 4.37     | 3.92  | NS       | 4.29           |       |
| 15-30 cm                |             |         |          |       |          |                |       |
| Forest                  | 33.5        | 4.70    | 12.91    | 6.38  | 6.67     | 9.17           | 12.22 |
| Grazing                 | 15.46       | 5.42    | 9.30     | 4.8   | 6.55     | 8.73           | 8.38  |
| Cultivated              | 8.94        | 5.27    | 9.81     | 10.55 | 8.84     | 11.13          | 9.09  |
| Orchard                 | 16.28       | 17.68   | 1.93     | 9.95  | 11.47    | 11.4           | 11.45 |
| Mean                    | 18.55       | 8.27    | 8.49     | 7.92  | 8.38     | 10.11          | 10.29 |
| SEm(±)                  | 2.36        | 0.83    | 1.06     | 0.78  | 1.48     | 0.78           |       |
| LSD (0.05)              | 7.68        | 2.7     | 3.47     | 2.54  | NS       | NS             |       |

Appendix 10 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on available potassium ( K<sub>2</sub>O kg ha<sup>-1</sup>)

| Treatments | Locations | Jhathornath | Kaniket | Antichak | Simra  | Poparava | Ambedkar Nagar | Mean   |
|------------|-----------|-------------|---------|----------|--------|----------|----------------|--------|
| 0-15 cm    |           |             |         |          |        |          |                |        |
| Forest     |           | 320.06      | 243.52  | 304.59   | 121.05 | 252.15   | 330.38         | 261.96 |
| Grazing    |           | 344.38      | 235.99  | 211.02   | 137.11 | 231.23   | 266.75         | 237.75 |
| Cultivated |           | 349.57      | 129.41  | 296.75   | 151.02 | 251.28   | 284.72         | 243.79 |
| Orchard    |           | 172.51      | 347.09  | 313.89   | 225.16 | 374.68   | 301.56         | 289.15 |
| Mean       |           | 296.63      | 239     | 281.56   | 158.59 | 277.33   | 295.85         | 258.16 |
| SEm(±)     |           | 16.13       | 8.61    | 10.5     | 8.67   | 7        | 10.54          |        |
| LSD (0.05) |           | 52.62       | 28.08   | 34.25    | 28.26  | 22.82    | 34.37          |        |
| 15-30 cm   |           |             |         |          |        |          |                |        |
| Forest     |           | 271.4       | 189.04  | 196.66   | 159.22 | 171.46   | 286.88         | 212.44 |
| Grazing    |           | 275.57      | 204.06  | 109.51   | 186.01 | 158.87   | 241.92         | 195.99 |
| Cultivated |           | 281.98      | 120.81  | 248.24   | 75.96  | 141.36   | 275.85         | 190.7  |
| Orchard    |           | 67.01       | 237.26  | 325.25   | 86.2   | 221.01   | 277.79         | 202.42 |
| Mean       |           | 223.99      | 187.79  | 219.92   | 126.85 | 173.18   | 270.61         | 200.39 |
| SEm(±)     |           | 6.48        | 12.86   | 69.39    | 14.87  | 11.08    | 15.34          |        |
| LSD (0.05) |           | 21.13       | 41.93   | NS       | 48.49  | 36.13    | NS             |        |

Appendix 11 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on DTPA extractable manganese ( $\text{mg kg}^{-1}$ )

| Locations<br>Treatments | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean  |
|-------------------------|-------------|---------|----------|-------|----------|----------------|-------|
| 0-15 cm                 |             |         |          |       |          |                |       |
| Forest                  | 40.87       | 43.76   | 64.93    | 54.76 | 25.78    | 66.53          | 49.44 |
| Grazing                 | 43.38       | 53.12   | 26.05    | 39.09 | 50.67    | 36.43          | 41.46 |
| Cultivated              | 23.98       | 47.74   | 51.59    | 24.81 | 70.92    | 25.12          | 40.69 |
| Orchard                 | 42.23       | 36.50   | 47.88    | 21.70 | 46.36    | 21.71          | 36.06 |
| Mean                    | 37.61       | 45.28   | 47.61    | 35.09 | 48.43    | 37.45          | 41.91 |
| SEm( $\pm$ )            | 1.52        | 1.13    | 1.95     | 1.04  | 0.89     | 2.13           |       |
| LSD (0.05)              | 4.94        | 3.68    | 6.37     | 3.39  | 2.91     | NS             |       |
| 15-30 cm                |             |         |          |       |          |                |       |
| Forest                  | 42.89       | 40.23   | 58.36    | 39.92 | 35.66    | 51.15          | 44.70 |
| Grazing                 | 40.40       | 47.32   | 20.94    | 43.52 | 44.54    | 27.95          | 37.45 |
| Cultivated              | 21.40       | 42.12   | 59.69    | 32.10 | 52.17    | 18.55          | 37.67 |
| Orchard                 | 40.80       | 39.74   | 36.90    | 15.41 | 48.06    | 20.70          | 33.60 |
| Mean                    | 36.37       | 42.35   | 43.97    | 32.74 | 45.11    | 29.60          | 38.36 |
| SEm( $\pm$ )            | 2.27        | 2.09    | 1.04     | 0.99  | 0.91     | 1.65           |       |
| LSD (0.05)              | 7.39        | NS      | 3.40     | 3.22  | 2.95     | 5.30           |       |

Appendix 12 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on DTPA extractable iron ( $\text{mg kg}^{-1}$ )

| Treatments   | Locations | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean  |
|--------------|-----------|-------------|---------|----------|-------|----------|----------------|-------|
| 0-15 cm      |           |             |         |          |       |          |                |       |
| Forest       |           | 42.94       | 33.47   | 34.74    | 48.38 | 35.97    | 58.51          | 42.34 |
| Grazing      |           | 42.39       | 26.37   | 31.02    | 41.87 | 49.22    | 52.61          | 40.58 |
| Cultivated   |           | 38.71       | 25.39   | 29.17    | 26.25 | 26.63    | 28.55          | 29.12 |
| Orchard      |           | 40.37       | 30.69   | 31.24    | 35.38 | 29.13    | 30.57          | 32.90 |
| Mean         |           | 41.11       | 28.98   | 31.54    | 37.97 | 35.24    | 42.56          | 36.23 |
| SEm( $\pm$ ) |           | 1.21        | 1.62    | 1.54     | 2.24  | 2.02     | 2.26           |       |
| LSD (0.05)   |           | NS          | 5.27    | NS       | 7.10  | 6.57     | 7.38           |       |
| 15-30 cm     |           |             |         |          |       |          |                |       |
| Forest       |           | 39.18       | 21.30   | 27.43    | 35.51 | 26.94    | 43.73          | 32.35 |
| Grazing      |           | 31.18       | 27.99   | 23.21    | 36.91 | 38.97    | 36.78          | 32.51 |
| Cultivated   |           | 29.65       | 19.68   | 21.69    | 22.37 | 22.54    | 25.21          | 23.52 |
| Orchard      |           | 32.54       | 23.14   | 23.10    | 30.85 | 24.23    | 26.69          | 26.76 |
| Mean         |           | 33.14       | 23.03   | 23.86    | 31.41 | 28.17    | 33.10          | 28.79 |
| SEm( $\pm$ ) |           | 1.68        | 2.15    | 1.48     | 2.29  | 1.19     | 2.84           |       |
| LSD (0.05)   |           | 5.48        | NS      | NS       | 7.46  | 3.88     | 9.29           |       |

Appendix 13 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on DTPA extractable copper ( $\text{mg kg}^{-1}$ )

| Locations<br>Treatments | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean |
|-------------------------|-------------|---------|----------|-------|----------|----------------|------|
| 0-15 cm                 |             |         |          |       |          |                |      |
| Forest                  | 2.73        | 2.7     | 2.24     | 3.16  | 2.68     | 3.7            | 2.87 |
| Grazing                 | 2.39        | 2.49    | 2.19     | 2.71  | 2.67     | 2.66           | 2.52 |
| Cultivated              | 1.87        | 2.27    | 1.78     | 2.43  | 2.61     | 2.62           | 2.26 |
| Orchard                 | 1.9         | 2.47    | 1.95     | 2.82  | 2.78     | 2.95           | 2.48 |
| Mean                    | 2.22        | 2.48    | 2.04     | 2.78  | 2.68     | 2.98           | 2.53 |
| SEm( $\pm$ )            | 0.16        | 0.13    | 0.12     | 0.10  | 1.02     | 0.17           |      |
| LSD (0.05)              | 0.51        | NS      | NS       | 0.34  | NS       | 0.55           |      |
| 15-30 cm                |             |         |          |       |          |                |      |
| Forest                  | 1.92        | 2.13    | 2.13     | 2.73  | 1.74     | 2.59           | 2.21 |
| Grazing                 | 1.83        | 2.02    | 1.47     | 2.43  | 1.66     | 2.38           | 1.97 |
| Cultivated              | 1.76        | 1.59    | 1.23     | 1.95  | 1.54     | 1.97           | 1.67 |
| Orchard                 | 1.86        | 2.03    | 1.55     | 2.43  | 1.69     | 2.22           | 1.96 |
| Mean                    | 1.84        | 1.94    | 1.59     | 2.38  | 1.66     | 2.29           | 1.95 |
| SEm( $\pm$ )            | 0.05        | 0.36    | 0.16     | 0.12  | 0.11     | 0.11           |      |
| LSD (0.05)              | NS          | NS      | 0.52     | 0.38  | NS       | 0.35           |      |

Appendix 14: Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on DTPA extractable zinc ( $\text{mg kg}^{-1}$ )

| Locations<br>Treatments | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean |
|-------------------------|-------------|---------|----------|-------|----------|----------------|------|
| 0-15 cm                 |             |         |          |       |          |                |      |
| Forest                  | 2.43        | 1.17    | 1.84     | 1.43  | 1.50     | 1.95           | 1.72 |
| Grazing                 | 1.82        | 1.73    | 1.44     | 1.17  | 1.57     | 1.78           | 1.59 |
| Cultivated              | 1.27        | 3.57    | 1.21     | 1.19  | 1.44     | 1.88           | 1.76 |
| Orchard                 | 1.22        | 2.54    | 1.16     | 1.87  | 1.65     | 1.11           | 1.59 |
| Mean                    | 1.69        | 2.25    | 1.41     | 1.41  | 1.54     | 1.68           | 1.66 |
| SEm( $\pm$ )            | 0.10        | 0.13    | 0.06     | 0.04  | 0.09     | 0.13           |      |
| LSD (0.05)              | 0.34        | 0.41    | 0.20     | 0.14  | NS       | 0.41           |      |
| 15-30 cm                |             |         |          |       |          |                |      |
| Forest                  | 2.04        | 1.15    | 1.40     | 1.52  | 1.45     | 3.24           | 1.80 |
| Grazing                 | 1.81        | 2.34    | 1.27     | 1.39  | 1.44     | 2.99           | 1.87 |
| Cultivated              | 1.15        | 2.66    | 1.35     | 1.07  | 0.95     | 2.12           | 1.55 |
| Orchard                 | 1.09        | 2.22    | 1.01     | 1.72  | 1.66     | 2.71           | 1.74 |
| Mean                    | 1.52        | 2.09    | 1.26     | 1.42  | 1.38     | 2.77           | 1.74 |
| SEm( $\pm$ )            | 0.06        | 0.07    | 0.07     | 0.06  | 0.12     | 0.12           |      |
| LSD (0.05)              | 0.18        | 0.21    | 0.24     | 0.20  | 0.40     | 0.39           |      |

Appendix 15 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on potassium permanganate extractable oxidizable carbon ( $\text{mg kg}^{-1}$ )

| Locations    | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean |
|--------------|-------------|---------|----------|-------|----------|----------------|------|
| Treatments   |             |         |          |       |          |                |      |
|              | 0-15 cm     |         |          |       |          |                |      |
| Forest       | 555         | 353     | 717      | 520   | 631      | 536            | 552  |
| Grazing      | 340         | 398     | 624      | 487   | 524      | 712            | 514  |
| Cultivated   | 448         | 646     | 443      | 375   | 431      | 406            | 458  |
| Orchard      | 550         | 526     | 580      | 523   | 462      | 509            | 525  |
| Mean         | 473         | 481     | 591      | 476   | 512      | 541            | 512  |
| SEm( $\pm$ ) | 42          | 35      | 56       | 25    | 38       | 27             |      |
| LSD (0.05)   | 136         | NS      | 183      | 82    | 126      | 88             |      |
|              | 15-30 cm    |         |          |       |          |                |      |
| Forest       | 407         | 311     | 506      | 359   | 385      | 413            | 397  |
| Grazing      | 325         | 389     | 471      | 348   | 353      | 374            | 377  |
| Cultivated   | 310         | 344     | 440      | 330   | 392      | 367            | 364  |
| Orchard      | 259         | 488     | 410      | 344   | 377      | 420            | 383  |
| Mean         | 325         | 383     | 457      | 345   | 377      | 394            | 389  |
| SEm( $\pm$ ) | 12          | 25      | 67       | 23    | 35       | 20             |      |
| LSD (0.05)   | NS          | NS      | NS       | NS    | NS       | NS             |      |

Appendix 16 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on water soluble carbon ( $\text{mg kg}^{-1}$ )

| Locations    | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar nagar | Mean |
|--------------|-------------|---------|----------|-------|----------|----------------|------|
| Treatments   |             |         |          |       |          |                |      |
|              | 0-15 cm     |         |          |       |          |                |      |
| Forest       | 232         | 186     | 150      | 238   | 192      | 94             | 182  |
| Grazing      | 170         | 104     | 134      | 118   | 137      | 71             | 122  |
| Cultivated   | 145         | 84      | 104      | 74    | 56       | 62             | 88   |
| Orchard      | 204         | 156     | 136      | 190   | 138      | 72             | 149  |
| Mean         | 188         | 133     | 131      | 155   | 131      | 75             | 135  |
| SEm( $\pm$ ) | 10          | 20      | 16       | 13    | 8        | 7              |      |
| LSD (0.05)   | 31          | 65      | NS       | 41    | 26       | NS             |      |
|              | 15-30 cm    |         |          |       |          |                |      |
| Forest       | 136         | 96      | 94       | 162   | 88       | 46             | 104  |
| Grazing      | 68          | 66      | 58       | 59    | 46       | 20             | 53   |
| Cultivated   | 59          | 53      | 52       | 40    | 23       | 19             | 41   |
| Orchard      | 74          | 73      | 84       | 96    | 71       | 23             | 70   |
| Mean         | 84          | 72      | 72       | 89    | 57       | 27             | 67   |
| SEm( $\pm$ ) | 12          | 5       | 9        | 15    | 11       | 4              |      |
| LSD (0.05)   | 40          | 17      | 30       | 49    | 37       | 12             |      |

Appendix 17 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on water soluble carbohydrate (mg kg<sup>-1</sup>)

| Locations  | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean |
|------------|-------------|---------|----------|-------|----------|----------------|------|
| Treatments |             |         |          |       |          |                |      |
|            | 0-15 cm     |         |          |       |          |                |      |
| Forest     | 549         | 604     | 257      | 220   | 447      | 408            | 414  |
| Grazing    | 479         | 453     | 451      | 128   | 335      | 376            | 370  |
| Cultivated | 131         | 444     | 217      | 659   | 354      | 280            | 348  |
| Orchard    | 489         | 532     | 302      | 270   | 356      | 461            | 402  |
| Mean       | 412         | 508     | 307      | 319   | 373      | 381            | 383  |
| SEm(±)     | 32          | 18      | 32       | 57    | 18       | 32             |      |
| LSD (0.05) | 104         | 60      | 104      | 185   | 60       | 105            |      |
|            | 15-30 cm    |         |          |       |          |                |      |
| Forest     | 137         | 233     | 131      | 122   | 220      | 120            | 160  |
| Grazing    | 154         | 231     | 173      | 70    | 143      | 131            | 151  |
| Cultivated | 62          | 151     | 229      | 69    | 257      | 99             | 145  |
| Orchard    | 144         | 177     | 121      | 128   | 233      | 125            | 155  |
| Mean       | 124         | 198     | 164      | 97    | 213      | 119            | 158  |
| SEm(±)     | 14          | 22      | 19       | 22    | 19       | 19             |      |
| LSD (0.05) | 44          | NS      | 62       | 72    | 63       | NS             |      |

Appendix 18 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on soil microbial biomass carbon (mg kg<sup>-1</sup>)

| Locations<br>Treatments | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean |
|-------------------------|-------------|---------|----------|-------|----------|----------------|------|
| 0-15 cm                 |             |         |          |       |          |                |      |
| Forest                  | 1060        | 840     | 780      | 1040  | 870      | 300            | 815  |
| Grazing                 | 220         | 460     | 520      | 450   | 920      | 800            | 562  |
| Cultivated              | 300         | 420     | 350      | 1540  | 740      | 420            | 628  |
| Orchard                 | 660         | 660     | 370      | 1180  | 840      | 580            | 715  |
| Mean                    | 560         | 595     | 505      | 1053  | 843      | 525            | 680  |
| SEm(±)                  | 54          | 58      | 66       | 168   | 109      | 71             |      |
| LSD (0.05)              | 176         | 190     | 216      | 210   | NS       | 231            |      |
| 15-30 cm                |             |         |          |       |          |                |      |
| Forest                  | 460         | 380     | 210      | 640   | 540      | 260            | 415  |
| Grazing                 | 80          | 330     | 290      | 330   | 680      | 340            | 342  |
| Cultivated              | 90          | 120     | 240      | 900   | 630      | 180            | 360  |
| Orchard                 | 300         | 310     | 270      | 570   | 578      | 360            | 398  |
| Mean                    | 233         | 285     | 253      | 610   | 733      | 285            | 379  |
| SEm(±)                  | 34          | 35      | 23       | 186   | 199      | 22             |      |
| LSD (0.05)              | 112         | 115     | NS       | 66    | NS       | 73             |      |

Appendix 19 : Effects of land use in different soil depths (0-15 and 15-30 cm) of different sites of Banka district on total organic carbon (%)

| Locations  | Jhathornath | Kaniket | Antichak | Simra | Poparava | Ambedkar Nagar | Mean |
|------------|-------------|---------|----------|-------|----------|----------------|------|
| Treatments | 0-15 cm     |         |          |       |          |                |      |
| Forest     | 1.76        | 1.62    | 1.83     | 1.39  | 1.15     | 2.04           | 1.63 |
| Grazing    | 1.73        | 1.74    | 1.37     | 0.66  | 1.14     | 1.79           | 1.40 |
| Cultivated | 1.23        | 1.91    | 0.88     | 0.76  | 1.66     | 1.74           | 1.36 |
| Orchard    | 1.27        | 2.14    | 1.36     | 0.90  | 1.35     | 1.50           | 1.42 |
| Mean       | 1.50        | 1.85    | 1.31     | 0.82  | 1.30     | 1.71           | 1.41 |
| SEm        | 0.03        | 0.12    | 0.09     | 0.03  | 0.04     | 0.07           | 0.06 |
| LSD (0.05) | 0.10        | NS      | 0.28     | 0.10  | 0.12     | 0.23           |      |
|            | 15-30 cm    |         |          |       |          |                |      |
| Forest     | 0.67        | 0.91    | 1.55     | 0.96  | 0.86     | 1.13           | 1.01 |
| Grazing    | 1.38        | 0.90    | 0.61     | 0.56  | 0.70     | 0.98           | 0.86 |
| Cultivated | 1.20        | 0.67    | 0.63     | 0.83  | 0.65     | 0.87           | 0.81 |
| Orchard    | 0.71        | 1.31    | 0.88     | 0.77  | 0.80     | 0.75           | 0.87 |
| Mean       | 0.82        | 0.91    | 0.85     | 0.53  | 0.67     | 0.93           | 0.79 |
| SEm        | 0.06        | 0.03    | 0.03     | 0.03  | 0.02     | 0.04           |      |
| LSD (0.05) | 0.20        | 0.11    | 0.11     | 0.11  | 0.08     | 0.13           |      |

Appendix 20 : Pearson correlation between land use and some soil properties in surface (0-15 cm) and subsurface (15-30 cm) soil

|            | Soil depth<br>(cm) | pH      |         | EC      |         | OC      |         | CEC     |         | BD     |         | MWHC    |        |
|------------|--------------------|---------|---------|---------|---------|---------|---------|---------|---------|--------|---------|---------|--------|
|            |                    | 0-15    | 15-30   | 0-15    | 15-30   | 0-15    | 15-30   | 0-15    | 15-30   | 0-15   | 15-30   | 0-15    | 15-30  |
| Forest     | EC                 | 0.88**  | 0.82**  |         |         |         |         |         |         |        |         |         |        |
|            | OC                 | 0.70**  | -0.23   | 0.84**  | -0.69** |         |         |         |         |        |         |         |        |
|            | CEC                | 0.08    | 0.42    | -0.07   | 0.27    | -0.15   | 0.21    |         |         |        |         |         |        |
|            | BD                 | 0.00    | -0.49*  | -0.41   | -0.12   | -0.61** | -0.35   | 0.56*   | -0.76** |        |         |         |        |
|            | MWHC               | 0.22    | -0.43   | 0.44    | -0.66** | 0.45*   | 0.28    | 0.44    | -0.47*  | -0.40  | 0.02    |         |        |
|            | MWD                | 0.55*   | -0.08   | 0.63**  | -0.37   | 0.46*   | 0.63**  | 0.52*   | 0.73**  | 0.00   | -0.79** | 0.38    | 0.05   |
| Grazing    | EC                 | 0.46*   | 0.34    |         |         |         |         |         |         |        |         |         |        |
|            | OC                 | 0.23    | -0.71** | 0.13    | -0.26   |         |         |         |         |        |         |         |        |
|            | CEC                | 0.67**  | 0.59**  | 0.66**  | 0.15    | 0.18    | 0.02    |         |         |        |         |         |        |
|            | BD                 | 0.45*   | -0.05   | 0.27    | -0.95** | 0.36    | 0.04    | 0.86**  | -0.06   |        |         |         |        |
|            | MWHC               | -0.15   | -0.17   | 0.27    | 0.29    | 0.19    | 0.74**  | -0.39   | 0.44    | -0.57* | -0.38   |         |        |
|            | MWD                | 0.93**  | 0.42    | 0.52*   | -0.43   | 0.54*   | 0.04    | 0.62**  | 0.44    | 0.44   | 0.56*   | 0.02    | 0.08   |
| Cultivated | EC                 | 0.96**  | 0.47*   |         |         |         |         |         |         |        |         |         |        |
|            | OC                 | -0.16   | -0.47*  | -0.16   | -0.47*  |         |         |         |         |        |         |         |        |
|            | CEC                | 0.79**  | -0.44   | 0.67**  | 0.57*   | -0.42   | 0.06    | 1.00    | 1.00    |        |         |         |        |
|            | BD                 | 0.09    | 0.08    | 0.28    | -0.03   | -0.75** | 0.11    | 0.04    | -0.01   | 1.00   | 1.00    |         |        |
|            | MWHC               | -0.61** | -0.40   | -0.44   | -0.50*  | 0.53*   | 0.03    | -0.70** | -0.23   | -0.04  | -0.83** | 1.00    |        |
|            | MWD                | -0.32   | -0.43   | -0.23   | -0.03   | -0.57*  | 0.54*   | 0.05    | 0.47*   | 0.60** | 0.68**  | 0.31    | -0.57* |
| Orchards   | EC                 | 0.84**  | 0.96**  |         |         |         |         |         |         |        |         |         |        |
|            | OC                 | 0.05    | -0.31   | 0.04    | -0.37   |         |         |         |         |        |         |         |        |
|            | CEC                | -0.63** | -0.03   | -0.75** | -0.12   | -0.59** | -0.23   |         |         |        |         |         |        |
|            | BD                 | -0.03   | -0.04   | -0.42   | -0.05   | 0.04    | -0.54** | 0.16    | -0.09   |        |         |         |        |
|            | MWHC               | 0.64**  | 0.45*   | 0.52*   | 0.43    | 0.49*   | -0.88** | -0.86** | 0.01    | 0.15   | 0.51*   |         |        |
|            | MWD                | 0.09    | -0.44   | -0.03   | -0.63** | -0.55*  | 0.23    | 0.61**  | 0.65**  | -0.32  | -0.16   | -0.60** | -0.16  |

\* represented the 0.05 level of significant and \*\* represented the 0.01 level of significant.

Appendix 21 : Pearson correlation between land use and active carbon pools in surface (0-15 cm) and subsurface (15-30 cm) soil

| Land use   | Carbon pools<br>Soil depths (cm) | WSC    |        | WSCHO   |        | PmOC    |        | MBC     |        |
|------------|----------------------------------|--------|--------|---------|--------|---------|--------|---------|--------|
|            |                                  | 0-15   | 15-30  | 0-15    | 15-30  | 0-15    | 15-30  | 0-15    | 15-30  |
| Forest     | WSCHO                            | 0.06   | 0.01   |         |        |         |        |         |        |
|            | PmOC                             | -0.44  | 0.02   | -0.65** | -0.51* |         |        |         |        |
|            | MBC                              | 0.38   | 0.65** | 0.95**  | 0.77** | -0.74** | -0.37  |         |        |
|            | TOC                              | -0.55* | -0.39  | 0.11    | -0.07  | 0.2     | 0.58** | -0.08   | -0.3   |
| Grazing    | WSCHO                            | 0.22   | 0.3    |         |        |         |        |         |        |
|            | PmOC                             | -0.11  | -0.41  | -0.08   | 0.01   |         |        |         |        |
|            | MBC                              | 0.44   | 0.55*  | 0.97**  | 0.96** | -0.09   | -0.10  |         |        |
|            | TOC                              | -0.1   | 0.04   | 0.81**  | 0.41   | -0.07   | -0.13  | 0.72**  | 0.37   |
| Cultivated | WSCHO                            | -0.57* | -0.21  |         |        |         |        |         |        |
|            | PmOC                             | 0.08   | -0.21  | -0.64** | 0.32   |         |        |         |        |
|            | MBC                              | -0.44  | -0.01  | 0.99**  | 0.98** | -0.69** | 0.29   |         |        |
|            | TOC                              | 0.10   | 0.22   | -0.58** | -0.55* | 0.16    | 0.08   | -0.62** | -0.52* |
| Orchards   | WSCHO                            | -0.54* | 0.73** |         |        |         |        |         |        |
|            | PmOC                             | -0.36  | -0.26  | -0.44   | -0.23  |         |        |         |        |
|            | MBC                              | -0.12  | 0.89** | 0.90**  | 0.96** | -0.71** | -0.25  |         |        |
|            | TOC                              | -0.20  | -0.20  | 0.75**  | -0.07  | -0.45*  | -0.50* | 0.78**  | -0.13  |

\* represented the 0.05 level of significant and \*\* represented the 0.01 level of significant.