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Effects of land use on soil physicochemical properties at Barkachha, Mirzapur District, Varanasi, India

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Types of land use practice significantly affect the soil physico-chemical properties. Four different land use types were selected (natural forest, bamboo plantation, degraded forest and agricultural land) to analyze the effect of land uses change on soil chemical and physical properties. Among all land use pattern, the highest water holding capacity (40.06±0.74%), porosity (0.539±0.011%), soil macro-aggregates (64.16±2.64%), soil organic carbon (0.84±0.054%) and soil total nitrogen (0.123±0.013%) were found to be under natural forest, closely followed in decreasing order by bamboo plantation, degraded forest and agricultural land. Unlikely, bamboo plantation was higher in moisture content (2.78±0.23%), whereas agricultural land was lower in moisture content (2.14±0.5%), though no significant differences were observed among land use types. Soil organic carbon was significantly affected by different land use practices. In contrast to this, agricultural land was higher in bulk density (1.37±0.0193 g/cm^3) whereas natural forest was lower in bulk density (1.220±0.0288 g/cm^3). Bulk density, soil organic carbon, soil total nitrogen, water holding capacity and porosity were significantly affected by land use changes. Furthermore, the correlation of analysis showed that soil organic carbon, soil total nitrogen, moisture content, porosity, water holding capacity, soil macro aggregates were positively correlated to each other and negatively correlated with bulk density, meso and micro soil aggregates at p<0.05. The results of this study will help to develop future plan about land use and soil management regarding soil carbon dynamics and climate change mitigation.

Key words: Land use type, land use change, soil physico-chemical properties.

INTRODUCTION

Land use change is one of the major drivers of global environmental change associated mainly with climate change, loss of biodiversity, reduction of soil fertility and changes in ecosystem services (Tilman et al., 2001;

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Ashagrie et al., 2007). It has a deep effect on soil organic carbon (SOC) storage, since it affects the amount and quality of litter input, litter decomposition rate, and stabilization of SOC. About 1500 Gt carbon (in 1 m soil depth) is reportedly present in soil organic matter, which is the largest of all the active terrestrial carbon pools (Eswaran et al., 2000). Among these, about 136±55 Gt carbon was estimated to be lost from soil organic matter stock due to land use change, thus can subsequently alter soil organic matter dynamics. Therefore, land-use change affects soil organic carbon accumulation and storage in soils, which in turns greatly influences the composition and quality of organic matter (Six et al., 2000; John et al., 2005; Helfrich et al., 2006). Land use change not only affects soil organic carbon but it also affects other nutrient contents of soil viz. Nitrogen, phosphorus etc. Restoration or reclamation of these degraded forests is of major concern and possess great challenge.

Soil organic matter has long been recognized as a determinant constitute of soil physical, chemical, and biological quality in general soil quality. In other words, soil organic matter is critically linked to soil physical and chemical properties (Li et al., 2013). Soil quality is the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health (Doran and Parkin, 1994). Thus, the capacity of a soil to function is often described as soil quality used to assess status of land or soil under various management systems (Ayobi et al., 2011). Soil quality indicator is a measurable soil property that affects the capacity of a soil to perform a specified function (Karlen et al., 1997). Soil properties that are responsive to the land use change are considered as suitable soil quality indicators (Carter et al., 1993). Among others various soil physico-chemical properties are considered as index of soil quality. Monitoring and mediating the negative consequences of land use change while sustaining the production of essential resources has therefore become a major challenge.

Nowadays, the practice of land use conversion, for instance from natural ecosystems to cultivated ecosystems is very common throughout the world (Vagen et al., 2006; Khormali and Nabiollahy, 2009). Maintaining soil quality (which includes various soil physical and chemical properties) is of major importance for any soil management system. Carbon sequestration has now been considered as one of the most effective mechanisms for mitigating the loss of soil carbon and related properties, by slowing or reversing the trend of increasing concentration of carbon dioxide in the atmosphere (Asante et al., 2011). Carbon sequestration in soil that is, accumulation of carbon in soil, refers to taking carbon dioxide from the atmosphere through plants and storing the carbon in the soil in the form of soil organic matter. In other words, carbon sequestration denote transferring atmospheric carbon dioxide into resistant pools with slow turnover and storing it firmly so that it is not released immediately (Lal, 2004).

Forests are one of the major ecosystems responsible for carbon sequestration, which cover about 30% of the land surface, store about 45% of total terrestrial carbon. In undisturbed natural forest ecosystems, the additions and losses of carbon are balanced over time and soil carbon stock reaches a stable equilibrium. Conversion of natural forest to other land use types is the major challenge for maintaining good soil quality. Other factors responsible for degradation of natural forests are excessive harvesting of woody and/or non-woody product of forest, grazing, poor management and other anthropogenic disturbances (ITTO, 2002). These disturbances, in turn, affect soil organic carbon accumulation and storage in soils, which greatly influences the composition and quality of organic matter. Plantation of *Jatropha curcas* (a perennial shrub of Euphorbiaceae family) in degraded land may be a good alternative for the reclamation of these degraded lands as the *J. curcas* is drought resistant and not preferred by the animal (Krishnamurthy et al., 2012). Information on the changes in soil physico-chemical properties due to land use changes are limited in general (Murty et al., 2002; Tripathi and Singh, 2009) and particularly lacking in dry tropics. The major objective of the present study is to analyze the effect of land use change on the potential of soil carbon sequestration in terms of the concentration of soil organic carbon.

MATERIALS AND METHODS

Study area and description of sites

The study was conducted in Baranas Hindu University, Varanasi, India from March to August, 2016. Samples were collected from Barkachha, Mirzapur district. Mirzapur is located at 25.15° N 82.58° E. It has an average elevation of 80 m (265 feet). It is a city in Uttar Pradesh, India, roughly 650 km from both Delhi and Kolkata, almost 89 km from Allahabad and 57 km from Varanasi. It has a population of 233,691 (2011 census). The climate in Mirzapur is warm and temperate. The mean annual temperature and rainfall is 26°C and 975 mm, respectively. The study area was classified into four sites based on their vegetation cover: Natural forest, degraded forest, bamboo plantation and agricultural land.

The forest in the study area is the mixed dry deciduous type dominated by *Acacia catechu* Wild., *Albizia odoratissima* (Benth.), *Acacia nilotica* (L.) *Willd*. *Boswellia serrata* Roxb., *Nyctanthes arbor-tristis* L*.,* with scattered trees of *(Azadirachta indica* Juss) and *Zizyphus glaberrima* Santap*.* The forest floor was covered with herbaceous vegetation comprising *Ocimum americanum.* L. *Pisum arvense* L., Rhynchosia *minima* (L.) DC., *Cassia sophera*(L.) Roxb., *Acrocephalus indicus* (Burm.f.), *Kuntze.*, *Cynodon dactylon* (L.) and *Oplismenus burmannii* Ritz. The degraded forest site was dominated by *Oryza glaberrima*, *Chrysopogon fulvus* (Spreng.), *Heteropogon contortus* (L.), *Adina cordifolia* Roxb. and scattered trees of *Butea monosperma* (Lamk.). Herbaceous vegetation in the degraded forest was dominated by *Cassia tora* L., *Oldenlandia diffusa. (*Willd.) Roxb., *Sporobolus* spp., *Panicumpsilopodium* Trin.

and *Alysicarpus vaginalis* (L.) DC

Soil sampling techniques

Soil samples were taken from four land use types (NF, DF, BP and AL) from the upper 15 cm depth for studying the impacts of land use change on soil physic-chemical properties. The natural forest was further divided into six sub-sites of 100 m × 100 m. From each sub-site, four soil samples were collected and mixed to represent the single composite sample of each study site. The same procedure was followed for degraded forest, bamboo plantation and agricultural land. The samples were immediately brought to the laboratory and were air dried for further analysis by Allen et al. (1974) and Waksman (1952).

Soil analysis

Soil physico-chemical characteristics (moisture, pH and organic content) were analyzed by standard methods as suggested by Allen et al. (1974) and Waksman (1952). For measuring soil moisture content, 10 g of fresh soil was dried at 105°C in oven to constant weight. Soil moisture content was calculated as:

$$\text{Soil moisture content (\%)} = \frac{\text{Weight of fresh soil} - \text{Weight of dry soil}}{\text{Weight of dry soil}} \times 100$$

For pH: Soil was dissolved in the sterilized distilled water in the ratio 1:5 and then measured the pH by using pH meter. Soil bulk density was determined by removing a known volume of soil using metal tubes and oven drying it at 105°C for 24 h. porosity expresses the relative amount of pore space in the soil. It is not measured directly but is calculated from the bulk density and particle density (Brady and Weil, 1996): it was calculated using the equation:

$[1 - (Db/Dp)] \times 100$

where Db = bulk density, Dp = particle density (assumed to be 2.65 Mg m-3 soil). The water holding capacity of the soil was determined using perforated circular brass boxes according to Piper (1966) method. Soil organic C was estimated by the dichromate oxidation and titration method (Kalembasa and Jenkinson, 1973). Total N concentration was measured by the micro kjeldahl method (Jackson, 1973) by using a Gerhardt digester and distillation unit.

Soil aggregates

Soil aggregates were determined by dry method according to Kemper and Chepil (1965). Air dried soil samples (100 g) were placed on a set of seven stacking of sieves and sieved for 3 min on a horizontal shaker (92 rpm), and three dry aggregate size classes separated were,1000 mm (macro-aggregate), 212-500 mm (meso-aggregate) and 53-150 (micro-aggregate).

RESULTS

Physico-chemical properties of the soil

The major physical properties of soils of different sites investigated are presented in Table 1 (pH, moisture content, aggregates, porosity, water holding capacity (WHC) and bulk density (BD)). As shown in Figure 1a, moisture content was highest in bamboo plantation (2.78%); while the lowest value was found in agricultural land (2.14%). However, no significant differences (at $p<0.05$) in moisture content were found among the land use types. The content of moisture in natural forest and degraded forest were 2.32 and 2.25%, respectively. Bulk density was found to vary significantly across the land use types; it was higher in agricultural land (1.37 g/cm^3), followed by degraded forest (1.25 g/cm^3), bamboo plantation (1.223 g/cm^3) and natural forest (1.22 g/cm^3). A significant difference in bulk density was observed between natural forest and other land use types (DF, BP and AL) but no significant different were observed among DF, BP and Al (Figure 1b). Soil porosity followed a reverse trend to that of bulk density. Porosity was significantly affected by land use change; it was higher in natural forest (0.539%) than bamboo plantation (0.538%); whereas the lowest was recorded in degraded forest (0.529%) and agricultural land (0.48%). So, significant difference was observed between natural forest and other land use types; whilst no significant difference was observed among degraded forest, bamboo planation and agricultural land (Figure 1c). The water holding capacity of natural forest, degraded forest, bamboo plantation and agricultural land is displayed in Figure 1d. Higher WHC (40.06%) was found in Natural forest and followed in decreasing order by bamboo plantation (38.51%), degraded forest (37.23%) and agricultural land (29.72%). There was a significant difference between agricultural land and other land use types in water holding capacity; whilst there was no significant difference among natural forest, degraded forest and bamboo plantation at $p<0.05$.

Soil aggregates

Soil aggregate is the naturally occurring cluster or group of soil particles and measures formation of organo-mineral complex (union of mineral and organic matter) in the soil. Across different land use types, macro-aggregates constituted (42-64%) of total soil followed by meso-aggregates (25-336%) and micro-aggregates (10-20%) (Table 2). Macro-aggregates were significantly higher in natural forest (64.16%) followed by bamboo plantation (51.65%), degraded forest (46.83%) and agricultural land (42.94%). Meso and micro-aggregates were higher in agricultural land followed by degraded forest, bamboo plantation and natural forest. The ANOVA results revealed that a significant difference in macro and meso-aggregates between natural forest and the other land use types. The micro-aggregates were also significantly affected by land use change; natural forest was significantly different with degraded forest and agricultural land but no significant difference with bamboo plantation.

Chemical properties of the soil

Results of the soil chemical properties (particularly

Table 1. Percentage of distribution of different dry aggregate soil size classes in different land use types and soil organic carbon (SOC) and soil total nitrogen (STN.

Soil aggregates (%)	Land use type				LSD
	NF	DF	BP	AL	
Macro-aggregates	64.16±2.64^{a}	46.83±1.00^{b}	51.65±5.4^{b}	42.94±1.11^{b}	8.48
Meso aggregates	25.68±2.48^{a}	35.16±0.73^{b}	33.10±4.74^{b}	36.39±1.69^{b}	9.28
Micro-aggregates	10.16±1.38^{a}	18.01±0.96^{b}	15.25±1.86^{ba}	20.66±1.81^{b}	4.65
SOC (%)	0.84±0.054^{a}	0.448±0.113^{b}	0.72±0.074^{a}	0.435±0.042^{b}	0.21
STN (%)	0.123±0.013^{a}	0.027±0.003^{b}	0.033±0.0034^{b}	0.014±0.0016^{b}	0.021

Values are mean ± SE. In each rows, values having different superscript are significantly different from each other ($p < 0.05$).

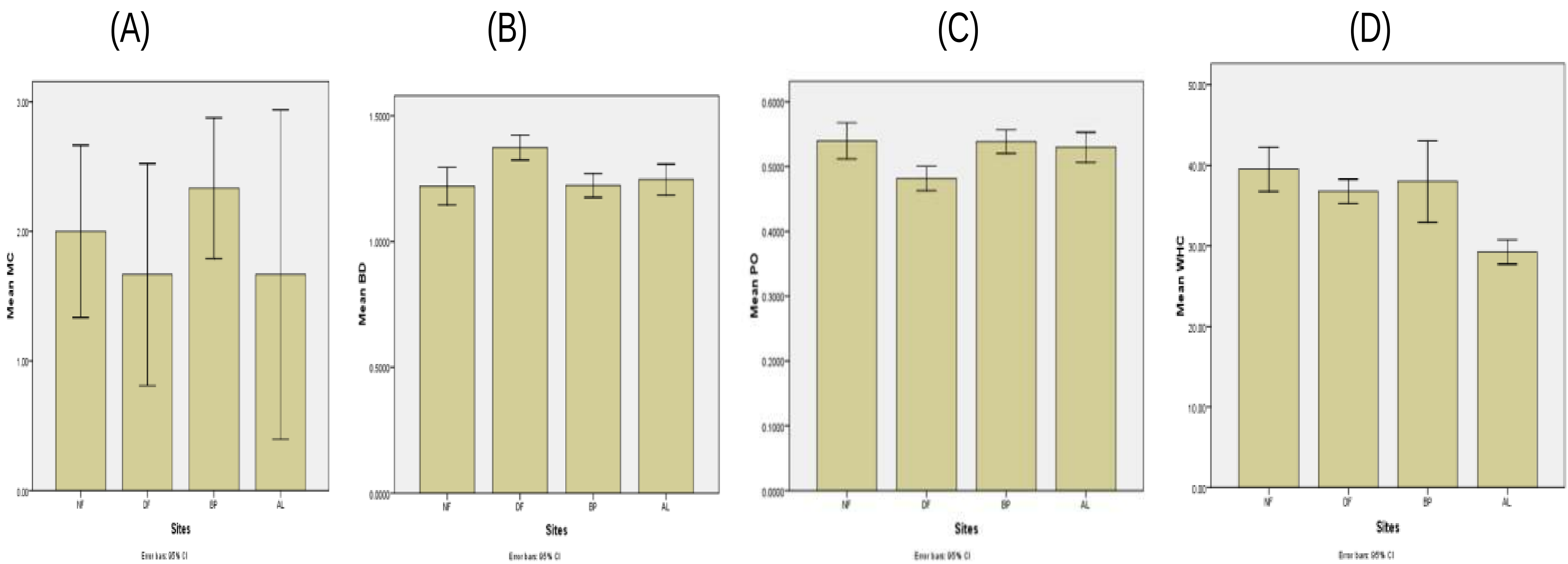

Figure 1. Comparison of MC, BD, porosity and WHC under different land use types: Natural Forest (NF), Degraded Forest (DF), Bamboo Plantation (BP) and agricultural Land (AL).

organic carbon and total nitrogen (tN)) of natural forest, degraded forest, bamboo plantation and agricultural land are presented in Table 1. Soil organic carbon and total nitrogen varied considerably across the land use types. The highest soil organic carbon was obtained from

Table 2. Correlation matrix for physical and chemical characteristics of soils from different land uses.

Soil variable	SBR	SOC	STN	MC	PO	WHC	BD	MA	ME
SOC	0.997**	1							
STN	0.815	0.828	1						
MC	0.583	0.548	0.01	1					
PO	0.758	0.703	0.555	0.615	1				
WHC	0.808	0.76	0.66	0.547	0.991**	1			
BD	-0.776	-0.722	-0.568	-0.624	-1.000**	-0.992**	1		
MA	0.926	0.929	0.970*	0.251	0.703	0.787	-0.717	1	
ME	-0.89	-0.901	-0.989*	-0.154	-0.623	-0.718	0.637	-0.994**	1
MI	-0.951*	-0.946	-0.936	-0.35	-0.778	-0.848	0.79	-0.993**	0.973*

BD, Bulk density; WHC, Water holding capacity; SOC, Soil organic carbon; STN, Total nitrogen; PO, Porosity; MA, Macro aggregates; ME, Meso aggregates; MI, Micro aggregates. Pearson's correlation coefficient, n = 4, * p < 0.05, ** p < 0.0.

natural forest (0.84%) followed by bamboo plantation (0.72%), degraded forest (0.448%) and agricultural land (0.435%). Soil organic carbon in natural forest and bamboo planation were significantly different with agricultural land and degraded forest; whilst there was no significant difference recorded between natural forest and bamboo planation, and degraded forest and agricultural land. Similarly, variation in soil total nitrogen concentration along the various land use types was found to be highest in natural forest (0.123%) followed in decreasing order bamboo plantation (0.033%), degraded forest (0.027%) and agro-ecosystem (0.014%). The analysis of variance showed that there was significant difference between natural forest and other land use types at $p<0.05$ in soil total nitrogen. However, no significant differences were observed among degraded forest, bamboo plantation and agricultural land.

Pearson's correlation coefficients between SOC, STN, moisture content, porosity, WHC, soil aggregates and bulk density is given in Table 2 (Singh and Ghoshal, 2014). SOC, STN and soil macro aggregates were strongly positively correlated to each other, and negatively correlated with bulk density, meso and micro soil aggregates. Additionally, soil organic carbon and total nitrogen were positively correlated with porosity (r=0.703 and 0.555), water holding capacity (r=0.76 and 0.66) and macro soil aggregates (r=0.929 and 0.970) while less/weakly correlated with moisture content (r=0.548 and 0.01). By contrast, soil organic carbon and nitrogen negatively correlated with bulk density (r=-0.722, and -0.568, $p<0.05$, respectively), soil meso (r= -0.901, -0.989, respectively) and micro aggregates (r= -0.946 and -0.936, $p< 0.05$, respectively). Macro soil aggregates was found to be significantly positively correlated with soil total nitrogen (r=0.97, $p<0.05$).

DISCUSSION

As per the finding of this study, the changes of tree species and composition was significantly affected the physical and chemical properties of soil. Natural forest found to be significantly higher in porosity, macro-aggregates, WHC but the least in bulk density, meso-aggregates and micro soil aggregates. In contrast, agricultural land found to be the higher in bulk density as compared to natural forest, bamboo plantation and degraded forest (Figure 1 and Table 1). This result supported by the study conducted by Tripathi et al., (2007) forest and mixed forest ecosystems were possess higher organic matter content compared to savanna and cropland ecosystems. According to Tripathi et al., (2007) soil physical and chemical properties can be significantly improved for the vegetation systems and Chen et al. (2010) land use change may lead to changes in soil physical, biological and chemical properties through their influence on various ecological processes.

Bamboo plantation (2.78%) was higher in moisture content followed by natural forest (2.32%), degraded forest (2.25%) and agricultural land (2.14%) but no statistically significant difference was found among the land use types (Figure 1a). This result was similar with earlier report by Pereira et al. (2013) the moisture of soil in re-forested Araucaria areas was higher as compared to natural forest and crop land. The reason for decreased soil moisture level in the cropland compared to forest ecosystems might be due to the decrease in organic matter and aeration following repeated cultivation, which may promote drying (Singh et al., 2009). Moreover, Singh et al. (2009) reported in cultivated soils, evaporation is a moisture-loss mechanism in the upper soil layer (0-10 cm) and there was about 17% decline in the soil moisture following cultivation. Natural forest was found to be higher in porosity and then in decreasing order bamboo planation, degraded forest and agricultural land (Figure 1c). This is suitable for adequate oxygen diffusion and water infiltration into the soil. This shows a good structural quality, favorable for the successful development of the biological community (Pereira et al., 2013).

Natural forest was significantly higher in WHC (40.06%)

than other three land use types. The WHC of bamboo plantation, degraded forest and agricultural land were (38.51%), (37.23%) and (29.72%). respectively (Figure 1d). This is comparable with other similar study elsewhere. For instance, Singh et al. (2009) reported WHC was greater in forest soils compared to savanna and cropland soils. Soil water is retained in pore spaces and adsorbed onto the surface of mineral and organic matter particles (Li et al., 2007). Cultivation primarily exhausts the labile pool of organic matter, for example, polysaccharides which are hydrophilic, creating a deficiency of adsorbent surfaces within soil and thereby diminishing its WHC (Li et al., 2007). Higher values of porosity in natural forest could be due to more organic matter content and high amount of fine fractions which has a higher surface area (Gupta et al., 2010).

Bulk density was highest in Agricultural land (1.37 g/cm^3) whereas lowest in natural forest (1.22 g/cm^3). The bulk densities of Bamboo plantation and degraded forest were (1.223 g/cm^3) and (1.25 g/cm^3), respectively (Figure 1b). Similarly, Goni et al. (2015) reported higher bulk density was found in wasted land and followed in decreasing order grass land, agricultural land and forest land. Zhang et al. (1988) and Singh et al. (1989) have also reported an increase in soil bulk density due to cultivation. This was probably due to decreased SOC and soil aggregation (Goni et al., 2015), as a result of repeated events of sowing and harvesting. Bot and Benites (2005) also reported that bulk density was lower in soils with high organic matter content.

Land use type displayed significant effect on the aggregate fraction (Table 1). Natural forest had more macro aggregate (64.16%) but lowest in meso (25.68%) and micro aggregates (10.16%). While agricultural land found to be the lowest in macro-aggregates (42.94%) whereas highest in meso (36.39%) and micro aggregates (20.66%). Similarly, in bamboo plantation the macro, meso and micro aggregates were 51.65, 33.10 and 15.25%, respectively; and in degraded forest the macro, meso and micro aggregates were 46.83, 35.16 and 18.01%, respectively. This could be due to the fact that no tillage in natural forest, lower disturbance and higher organic matter input (litters and root exudates) that bind soil aggregates together resulting in improved soil structure formation. By contrast, degraded forest and agricultural land showed lower aggregates due to lower OC content and more micro fraction, respectively attributed to continuous cultivation and rapid oxidation of SOM (Bot and Benites, 2005).

Soil organic C and N is considered to be one of the major attributes of soil fertility and agricultural sustainability (Lal, 2002). As per the finding of this study, the highest organic carbon was found to be under natural forest (0.84%) and the lowest organic carbon was found to be under agricultural land (0.435%). Degraded forest and agricultural land organic carbon were found 0.448 and 0.435%, respectively. Similarly, the highest organic nitrogen was found under natural forest (0.123%) and the lowest organic nitrogen was found under agricultural land (0.014%). Degraded forest and agricultural land organic nitrogen were found 0.027 and 0.033%, respectively (Table 2). This is comparable with other similar studies elsewhere. For instance, Singh and Ghoshal (2011), and Pereira et al. (2013) reported forest had higher in organic carbon and nitrogen than Jatropha plantation/reforested area, degraded forest and lowest in agroe-cosystem; while others reported higher soil organic carbon content in natural forest than tilled crop lands (Gol, 2009). Similarly, Iqbal et al. (2015) also reported the highest soil organic carbon was obtained from agroforestry followed by grass land and fallow land. Highest soil organic carbon concentration in natural forest was might be due to the regular addition of plant litter including above and below ground plant parts, and limited disturbances like grazing, logging, lack of tillage, high plant biodiversity, and root exudates (Goni et al., 2015). Moreover, due to an increased return of residues from high root biomass contributing to the storage and stabilization of SOC in aggregates (Goni et al., 2015; Srivastava and Singh, 1991).

The conversion of natural forest to degraded forest was significantly decreased SOC and tN. The disturbances associated with deforestation might have led to loss of vegetation which in turn have resulted in land degradation, erosion and subsequently the considerable losses of soil organic carbon and nutrients (Tripathi and Singh, 2009; Xiangmin et al., 2014). Changes in land use pattern through changes in type and diversity of plants are reported to exert major influence on the transfer and accumulation of carbon in soil (Tilman et al., 2006). In addition, degradation of natural forest leads to opening of the canopy cover and increases the interference of physical factors such as light intensity, wind velocity and soil moisture content. As the canopy opens, incident light intensity and wind velocity increase, decreasing the moisture content, this, in turn, stimulates organic matter mineralization.

Bamboo plantation was relatively less organic carbon and nitrogen as compare to natural forest, but higher than degraded forest and agricultural land. This increase in soil organic carbon and nitrogen in bamboo plantation was probably due to addition of nutrient rich leaf litter to soil and also due to recycling of these nutrients (Chaudhary et al., 2008; Behera et al., 2010). In contrast to this, the amount of SOC and tN was significantly lower in agricultural land. According to Jenkinson and Rayner (1977), Paul et al. (1997), Tripathi et al. (2007), Saha et al. (2010) studies agricultural practice decreased the level of organic carbon and nitrogen in the soil. Similarly, Poeplau et al., (2010) illustrated that native lands typically stored higher amounts of soil organic carbon than crop lands under similar site conditions because of higher residue inputs and reduced turnover. However, Tripathi et al., 2007) also reported that the SOC and N losses from an agricultural land can be due to its removal of crops. The lowest level of SOC and N from cultivation land may be due to continues tillage practice that accelerates native SOM oxidation by destructing soil aggregates and exposing newer sites to microbial attack which in turn have resulted in loss of SOC (Singh and Ghoshal, 2006).

Conclusion

Soil physico-chemical properties were significantly affected by land use change. Water holding capacity, porosity, soil macro-aggregates, soil organic carbon, and soil total nitrogen were found to be higher in natural forest followed by decreasing order bamboo plantation, degraded forest and agricultural land. In contrast to this, agricultural land was higher in bulk density as compared with other land use types whereas natural forest was lower in bulk density. Soil organic carbon, soil total nitrogen, moisture content, porosity, water holding capacity, soil macro aggregates were positively correlated to each other and negatively correlated with bulk density, meso and micro soil aggregates.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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