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Impact of different Land-Use Systems on Selected Soil Physicochemical Properties in Biligirirangana Hills, Chamarajanagara District

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Abstract

Soil physical and chemical properties play a vital role in sustainable utilization of soil resources. In order to study the physical and chemical properties, six different land-use systems were selected *viz.,* natural forest, forest plantations, pure coffee plantations, coffee multi-storeyed system, agriculture monocropping system and agriculture mixed cropping system. The representative soil samples were collected at 0-15 cm, 15-30 cm and 30-45 cm depth. The two way analysis of variance was used to test the mean differences of the soil physical and chemical properties. The present investigation revealed that soil texture was sandy loam to sandy clay loam. The mean bulk density of the soils ranged from 1.08 and 1.45 g cm^{-3} and the mean total porosity ranged from 45.80 - 66.31 per cent. The soil pH was acidic in all land use systems and electrical conductivity was normal. Natural forest shows significantly the highest mean value of organic carbon (37.09 g kg^{-1}) and the lowest mean value observed in paddy land use system (8.5 g kg^{-1}). However, the mean values of available N ranged from 263.42 kg ha^{-1} to 415.00 kg ha^{-1}. The highest average (97.64 and 665.60 kg ha^{-1}) available P_2O_5 and K_2O was recorded on the pure coffee plantations and the lowest (64.89 and 379.40 kg ha^{-1}) was recorded on the agriculture monocropping respectively. Conversion of natural forest to different land use systems has adverse effects on soil physical and chemical properties. Therefore, land use systems in the region are vulnerable to land use change and must adopt suitable management practice to enhance soil fertility and productivity.

Keywords : Natural forest, Forest plantation, Coffee based land use, Agriculture mono and mixed cropping, Soil depth, Soil properties

Environmental degradation caused by inappropriate land use is a worldwide problem that has attracted attention in sustainable agricultural production systems (Agoume and Birang, 2009). Globally, land-use changes associated with forestry and agriculture, such as deforestation and subsequent conversion to agriculture, are estimated to be responsible for 25 per cent of the accumulated GHG (greenhouse gas) emissions. Land-use changes in the tropics are responsible for approximately 10 per cent of the human induced greenhouse gas emissions and are expected to remain the second largest source of carbon (C) emissions in the near future (Achard *et al*., 2014). The soil productivity and sustainability of soil depends on dynamic equilibrium among its physical, chemical and biological properties (Ahmed, 2012).

In the Indian context, about 275 million people, comprising nearly 27 per cent of the country's population, depend on forests for their subsistence or livelihoods (World Bank 2006). The increasing demand for forest resources from global markets have contributed to the increased rates of conversion of forests to plantation crops (Vliet *et al.* 2012). Several researchers have studied the effect of land use on soil properties that provides an opportunity to evaluate sustainability of land use systems. Lal (1996) and Shepherd *et al.* (2000) examined that land use changes in tropical ecosystems could cause significant modifications in soil properties. The conversion of tropical forests into other land uses such as plantations and croplands through anthropogenic activities may act as a carbon loss (Fan *et al.,* 2016, Iqbal and Tiwari, 2016) leading to alterations of soil properties and processes. In this context a study was conducted to know the Impact of different land - use systems on selected soil physicochemical properties in Biligirirangana hills, Chamarajanagara District.

Material and Methods

Study Area

The present study was carried out in Biligirirangana Hills a chain of hills and important ecosystems, which forms the biogeographic ridge between two biodiversity rich areas namely the Western Ghats and the Eastern Ghats of India, located in Chamrajanagar District, south-eastern part of Karnataka. The region extends between 11p 402 - 12p 062 N latitude and 76p 242 - 77p 462 E longitude and the altitude ranges from 1400 - 1800 m above MSL wide variation in mean temperature (9p C to 16p C minimum and 20p C to 38p C maximum) and annual rainfall (600 mm at the base and 3000 mm at the top of the hills).

The study area consists of different predominant land use / land cover types including agriculture (cotton, maize) and plantation crops (coffee, pepper, forest plantation trees etc.) have widely replaced many of the native forests. To assess the soil physico-chemical properties among different land uses, six landuse, types were identified in BR hills, *viz.* 1) Natural Forest, 2) Forest plantations, 3) Pure coffee plantations, 4) Coffee multi-storeyed system, 5) Agriculture monocropping system and 6) Agriculture mixed cropping system.

Soil Sampling and Analysis

In each land use system, five quadrats measuring 20 m x 20 m were randomly laid down in such a way that it is a representative of the land use studied. Within each quadrat, soils were collected from ten points (5 in the corners and 5 in the centre) at three depth classes *i.e.* 0-15, 15-30 and 30-45 cm respectively. The five sub-samples at each location and depth class were pooled to get one composite sample for each depth class per plot. A total of 180 samples were collected from different landuse system. The soils were mixed thoroughly and large plant debris, roots and stones were removed manually by hand. Equal number of soil samples from the same depths was collected from undisturbed plots separately for bulk density by using soil corer of known volume. In the laboratory, the soil samples were homogenized, air-dried, grounded and passed through 2 mm sieve for further analysis.

Physico Chemical Analysis of the Soil

Air-dried soil samples were used for analyses of texture, bulk density, pH, organic C, available N and P_2O_5 and exchangeable cations *i.e.* K, Ca and Mg. Soil texture was assessed using a International pipette method as described by Black (1965). Bulk density was determined by the laboratory method for disturbed soil as per the procedure described by Gupta (2007). Soil pH, electrical conductivity in soil samples was measured in 1:2 soil : water extract as outlined by Jackson (1973). Organic C was estimated by Walkley and Black (1934) rapid titration method. The per cent soil organic carbon content in the natural forest considered as reference base (100%) for the calculation for per cent depletion in soil organic carbon, when natural forest converted into different land use systems. The alkaline potassium permanganate method was adopted to assess the available nitrogen content in soils (Subbaiah and Asija, 1956). The available phosphorus in the soil samples determined by Bray's No.1 reagent (0.03 NH4F + 0.025 N HCl) (Jackson, 1973). The available sulphur was determined as described by Black (1965). Available potassium was extracted with 1 M ammonium acetate at pH 7 and measured using a flame photometer (Page *et al.*, 1982).

Statistical Analyses

Analysis of variance (ANOVA) at 95 per cent confidence level was analyzed taking sampling sites as replicates (random effects) and land use types as treatments (fixed effects) using MS EXCEL and using SPSS for windows (IBM SPSS *ver.* 17.0).

Results and Discussion

Effect of different Land-use Systems on Physical Properties of Soil

Particle Size Distribution

The soils of different land use systems were sandy loam to sandy clay loam in texture. Among different land use systems, the highest mean value of sand content was observed in natural forest 58.00 per cent and the lowest mean value was observed in agriculture monocropping 51.15 per cent. The highest mean value of silt content was observed in forest plantation 26.41 per cent and the lowest mean value was observed in coffee multi-storeyed system 24.03 per cent. The highest mean value of clay content was observed in agriculture mixed cropping 22.43 per cent and the lowest mean value was observed in natural forest 17.73 per cent (Table 1). The soil texture in different land use systems varied from sandy loam to sandy clay loam. This could probably due to soils which were derived from coarse grained parent materials. The soils were dominant in sand content but the accumulation of clay and silt were observed in the subsurface layer with decrease in sand content. Similar results have been reported by Joshi (2004). According to the results of analysis of variance (ANOVA) revealed that there was a significant difference on the sand and clay particle under different land use systems and soil depths. The sand content significantly decreased with increasing depth whereas the clay content increases significantly with increasing depth. But there was no significant difference in the silt content among different land use and different depths. Considering the combination of land use types with soil depth, the highest (60.03%) and the lowest (49.83 %) value of sand was found on the surface (0-20 cm) soil layer of coffee multi-storeyed system and subsurface layer (30-45 cm) of agriculture monocropping, respectively (Table 1). Whereas the highest (23.78 %) and lowest (15.75 %) values of clay content were found in the subsurface (30-45 cm) soil layer of the agriculture monocropping and surface layer of natural forest lands, respectively (Table 1). Under different soil depth, the higher sand content was obtained at the surface (0-20 cm) soil layer, whereas the higher silt and clay were recorded in the subsurface (30-45 cm) of soil layer (Table 1). Generally, the clay content was higher in the subsurface layer of cultivated agriculture land as compared to the adjacent natural forest, forest plantations and coffee based land use systems, might be Higher content of finer fraction in lower soil depth might be due to the translocation of finer particles from the surface horizons and subsequent illuviation in subsurface horizons; these results are in conformity with the findings of Khan and Chatterjee (2001). Similarly, Chemada *et al*. (2017) stated that the clay content of cultivated land was increased from the surface to subsurface soil layer due to the long period of cultivation. Additionally, Gebrelibanos and Assen (2013) reported that lower clay and higher sand content was found in the surface layer and higher clay contents was found in the subsurface layer of cultivated land than the others adjacent natural forest, plantation forest and grazing lands.

Bulk Density

The soil bulk density value was significantly affected by land use and soil depth at P d' 0.01 (Table 1). Considering the land use types, the highest (1.45 g cm^{-3}) mean value of bulk density was recorded on the sub surface layer (30-45 cm) agriculture monocropping system and the lowest (1.08 g cm^{-3}) mean value was found under the surface layer of forest plantation (Table 1). This might be due to the continuous addition of organic matter with minimum tillage treatments under plantation and coffee based land use reduces the breakdown of soil aggregates which helps to reduce the bulk density. Additionally, Takele *et al.* (2014) and Abad *et al.* (2014) suggested that the bulk density of cultivated land was higher than that of adjacent grazing land and forest lands at soil depth of 0-30 cm. However in case of annual crops due to continuous cultivation, the soil aggregates are broken down into small soil particles, as the size of the soil particles decreases the bulk density increases. These results are in conformity with the findings of Gajri and Majumdar, (2002). It was found that the higher bulk density values were recorded in the subsurface layers of the soil (30-45 cm) as compared

TABLE 1

Physical properties of soils under different land use systems of Biligirirangana hills

Land use systems	Depth (cm)	Particle size (%)			Textural class	BD (g cm^{-3})	Total porosity (%)
		Sand	Silt	Clay			
Natural forest	0-15	59.31	24.88	15.75	SL	1.05	57.94
	15-30	58.33	24.23	17.26	SL	1.15	54.14
	30-45	56.36	25.10	20.18	SL	1.56	37.40
	Range	56.36 - 59.31	24.23 - 25.10	15.75 - 18.18		1.05 - 1.56	37.40 - 57.94
	Mean	58.00	24.74	17.73		1.25	49.83
Forest plantation	0-15	57.96	24.59	17.23	SL	1.08	66.31
	15-30	54.20	26.95	18.65	SL	1.11	56.77
	30-45	51.56	27.70	20.69	SCL	1.15	53.94
	Range	51.56 - 57.96	24.59 - 27.70	17.23 - 20.69		1.08 - 1.15	53.94 - 66.31
	Mean	54.57	26.41	18.85		1.11	59.01
Pure coffee plantations	0-15	57.70	23.90	18.24	SL	1.05	58.19
	15-30	55.14	23.91	20.67	SCL	1.12	55.15
	30-45	52.57	25.05	22.32	SCL	1.26	49.76
	Range	52.57 - 57.70	23.90 - 25.05	18.24 - 22.32		1.05 - 1.26	49.76 - 58.19
	Mean	55.14	24.29	20.41		1.14	54.37
Coffee multi-storeyed system	0-15	60.03	23.35	18.01	SL	1.05	58.01
	15-30	57.75	24.33	18.68	SL	1.11	55.79
	30-45	55.72	24.42	19.62	SL	1.20	51.89
	Range	55.72 - 60.03	23.35 - 24.42	18.01 - 19.62		1.05 - 1.20	51.89 - 58.01
	Mean	57.83	24.03	18.77		1.12	55.23
Agriculture mono-cropping system	0-15	53.00	24.99	21.81	SCL	1.29	48.42
	15-30	50.61	26.25	22.99	SCL	1.31	47.43
	30-45	49.83	26.23	23.78	SCL	1.32	47.09
	Range	49.83 - 53.00	24.99 - 26.23	21.81 - 23.78		1.29 - 1.32	47.09 - 48.42
	Mean	51.15	25.82	22.86		1.31	47.65
Agriculture mixed cropping system	0-15	53.93	24.73	22.06	SCL	1.22	51.19
	15-30	52.18	25.47	22.19	SCL	1.32	47.03
	30-45	50.49	26.33	23.05	SCL	1.35	45.81
	Range	50.49 - 53.93	24.73 - 26.33	22.06 - 23.05		1.22 - 1.35	45.81 - 51.19
	Mean	52.20	25.51	22.43		1.30	48.01
	CD (P = 0.05)	1.484	1.715	0.876		0.168	0.678
	SEm±	0.453	0.409	0.295		0.007	0.292
	CV (%)	44.87	51.83	26.50		0.50	20.35

to surface soil might be due to low soil organic matter was responsible for increased bulk density.

Total Porosity

The result of the analysis of variance (ANOVA) showed that the total porosity of soil was significantly affected by land use types and soil depth (Table 1). Considering the land use types with soil depth, the highest (66.31%) and the lowest (45.81%) values of total porosity was recorded on the surface soil layer of forest plantations and subsurface layer (30-45 cm) of the agriculture mixed cropping, respectively (Table 1). The higher value of soil total porosity in forest plantations was implied that the low bulk density of forest plantation. The mean total porosity of forest plantation, natural forest, coffee multi-storeyed, pure coffee, agriculture mixed cropping and agriculture monocropping were 59.01, 53.97, 55.23, 54.37, 45.01 and 47.65 per cent, respectively (Table 1). In the case of all soil depths, the higher value of total porosity was recorded at the surface soil layer. The total porosity varies across the different land use types was implies to the bulk density values of that respective soil.

Chemical Properties of Soils under different Land use Systems

Soil pH

In all the land use systems the soil pH was acidic in nature. The highest mean value of soil pH was found under coffee multi-storeyed system (6.29) followed by pure coffee plantations (6.20) and the lowest mean value was observed in forest plantations (5.58). The variation may be attributed to change in rainfall pattern, topographic position, rhizosphere microbial activity and rate of decomposition. These results are in agreement with the findings of Ananthkumar (2011). In all the land use systems the soil pH was increased with increase in soil depth. The analysis of variance results indicated that the soils pH-H_2O significantly affected by land use types but not in soil depth (Table 2). Considering the interaction of land use types with soil depth, the highest (6.35) and the lowest (5.46) values of soil reaction were recorded on the surface (0-15 cm) soil layer of coffee multi-storeyed system and forest plantations, respectively (Table 2). Compared with the others land use types, the lowest mean value of soil reaction was observed under the forest land use compare to cultivated land use. This might be due

TABLE 2

Chemical properties of soils under different land use systems of Biligirirangana hills, Chamarajanagara district

Land Use System	Depth (Cm)	pH	EC (dS m^{-1} at 25^{0}C)	OC (g kg^{-1})
Natural forest	0-15	5.66	0.427	45.9
	15-30	5.80	0.330	37.02
	30-45	5.64	0.326	28.35
	Range	5.64-5.80	0.326-0.427	28.35-45.9
	Mean	5.70	0.361	37.09
Forest plantation	0-15	5.46	0.241	40.11
	15-30	5.67	0.347	32.43
	30-45	5.62	0.426	22.92
	Range	5.46-5.67	0.241-0.426	22.92-40.11
	Mean	5.58	0.338	31.82
Pure coffee plantation	0-15	6.27	0.564	35.61
	15-30	6.19	0.437	23.73
	30-45	6.16	0.701	17.31
	Range	6.19-6.27	0.564-0.701	17.31-35.61
	Mean	6.20	0.57	25.55
Coffee multi-storeyed system	0-15	6.35	0.587	30.69
	15-30	6.27	0.603	26.91
	30-45	6.25	0.708	0.51
	Range	6.25-6.35	0.587-0.708	20.51-30.69
	Mean	6.29	0.633	26.04
Agriculture monocropping system	0-15	6.10	0.249	10.24
	15-30	6.15	0.417	7.99
	30-45	6.07	0.300	7.27
	Range	6.07-6.15	0.249-0.300	7.27-10.24
	Mean	6.10	0.322	8.5
Agriculture mixed cropping system	0-15	6.02	0.222	16.53
	15-30	6.09	0.387	12.84
	30-45	6.19	0.571	7.62
	Range	6.02-6.19	0.222-0.571	7.62-12.84
	Mean	6.10	0.393	12.33
CD (P = 0.05)		0.070	0.021	0.114
S.Em ±		0.025	0.013	0.089
CV (%)		2.11	0.63	3.47

to the continuous input of forest litter and subsequent release of organic acids, which decrease the soil pH.

Soil pH increased consistently with increased in soil depth in all land use systems even though, which might be due to leaching of basic cations due to high rainfall. The lowest mean value of pH was observed in 0 to 15 cm soil depth (5.46), these results are supported by Rudramurthy *et al.* (2007).

Electrical Conductivity

The electrical conductivity (EC) values of soils were significantly affected by land use types and soil depths (Table 2). It was increased marginally with increasing soil depth in all the land use systems. The highest mean value of EC was found in coffee multi-storeyed (0.633 dS m^{-1} at 25^{ϵ} C) followed by pure coffee plantation (0.57 dS m^{-1} at 25 ^{0}C) and lowest was observed in agriculture mono cropping (0.322 dS m^{-1} at 25 ^{0}C) followed by natural and forest plantations. Considering the combine effects of land use types and depths, the highest (0.708 dS m^{-1}) and the lowest (0.222 dS m^{-1}) EC of the soils were obtained in the coffee multi-storeyed and the agriculture mixed cropping, respectively (Table 2). The lowest EC value under the natural forest and forest plantations could be associated with the loss of base forming cations through high water percolation since natural forest and forest plantations had a low bulk density and higher total porosity. Similarly, this result is in agreement with findings of Mesele *et al.* (2006) who found the lower electrical conductivity under grassland compared to the adjacent croplands, bush lands and bushed-grasslands at 0-20 cm of soil depth. The movement of salts from surface soil layer to subsurface layer through water might have contributed for slightly higher conductivity value (irrespective of soil depth). The lowest mean value of EC was found in 0 to 15 cm in different land use systems this may be mainly due to variation in soluble salts in soils and variation in the degree of leaching loss of salts from soils due to the intensity of rainfall and restricted drainage. These results are in line with the findings of Nagaraj *et al.* (2002).

Soil Organic Carbon

The analysis of variance results revealed that the SOC (Soil Organic Carbon) contents were significantly affected by land use types and soil depth (Table 2). Natural forest shows the highest mean value of organic carbon (37.09 g kg^{-1}) followed by forest plantations (31.82 g kg^{-1}) and the lowest mean value observed in agriculture monocropping system (8.5 g kg^{-1}). In all the land use systems the organic carbon status decreases with increasing soil depth. Considering the combined effects, the highest (45.9 g kg^{-1}) value of SOC content was recorded on the surface (0-15 cm) soil layer of natural forest land and the lowest (7.27 g kg^{-1}) value of SOC was found under the subsurface (30-45 cm) soil layer of agriculture monocropping system (Table 2). However, the highest value of SOC on the surface layer of forest land use systems was attributed to the excessive amount of plant residues and biomass on surface land. This finding is in agreement with different individual's findings Chibsa and Taa (2009), Iqbal *et al.* (2012) and Takele *et al.* (2014) in which they reported that the SOC decrease with increasing soil depth, with more accumulation on the upper surface soil layer.

The per cent soil organic carbon content in the natural forest considered as reference base (100%) for the calculation for per cent depletion in soil organic carbon, when natural forest converted into different land use systems. The percentage of carbon removal takes place in the following order *i.e.* agriculture monocropping (78.4%) > agriculture mixed cropping (73.1%) > coffee multi-storeyed system (38.9%) > pure coffee plantation (33.1%) > forest plantations (19.2%) in surface layer and similar trend was in other two soil depths (Fig. 1). Highest carbon loss was observed in agriculture based land use systems compared to tree based land use because of continuous disturbance of soil through tillage activities and less input of litter or plant residues in the agriculture systems.

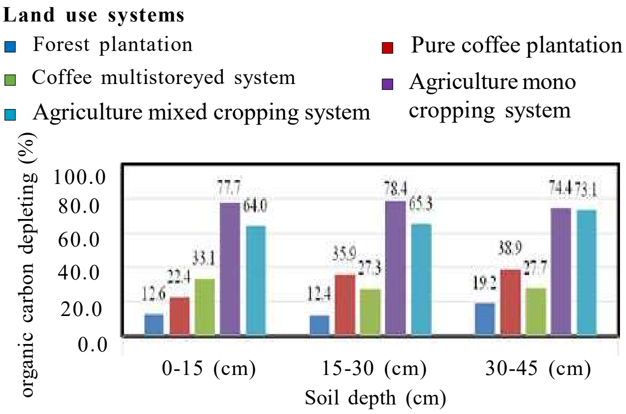

Fig. 1 : Per cent soil organic carbon depletion under different land use systems compared to natural forest (100%)

Available Nitrogen

The available nitrogen (N) content of soils was significantly affected by land use types and soil depth (Tables 3). Regarding to the main effects of land use types and soil depths, the average value of available N was highest (415.00 kg ha^{-1}) on the pure coffee plantations and lowest (263.42 kg ha^{-1}) on the agriculture monocropping (Table 3). The variations of available N content among different land use types are parallel with that of OM content, which is decreasing while soil depth was increased. The higher available N content in soils of the forest land could be associated with the high OM contents of the soils, whereas the low content of available N in agriculture land use might be due to the less regularly addition of litter input and cultivation of land causes loss of soil organic carbon. Further, removal of vegetation by livestock grazing and expose the surface layer of agricultural land to direct rain drop could be generating more surface runoff, which can remove the animal and plant residues from the surface soil layer thereby cause for nitrogen depletion. Similarly, Nigussie and Kissi (2012), Ufot *et al*. (2016), Tufa *et al*. (2019) and Chemada *et al*. (2017) stated that the higher total N was obtained under forest land compared to the adjacent grazing and cultivated lands.

Available Phosphorous and Potassium

The analysis of variance results indicated that the available phosphorous and potassium of the study area was significantly affected by land use types and soil depth (Tables 3). The available phosphorous and potassium was higher in the surface soil layer than in the subsurface soil layer. Generally, variations in available phosphorous and potassium contents in soils could be related to the intensity of soil weathering or soil disturbance under

TABLE 3

Available major nutrient status of soils under different land use systems of Biligirirangana hills, Chamarajanagara District

Land Use System	Depth (Cm)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
Natural t fores	0-15	435.90	72.21	492.08
	15-30	426.50	52.90	503.44
	30-45	316.74	58.99	454.59
	Range	316.74-435.90	58.99-72.21	454.59-03.44
	Mean	393.05	61.37	483.37
Forest plantation	0-15	451.58	77.73	433.63
	15-30	388.86	77.05	443.52
	30-45	297.92	57.40	374.83
	Range	297.92-451.58	57.40-77.73	374.83-43.52
	Mean	379.46	70.73	417.33
Pure coffee plantation	0-15	492.35	102.29	719.16
	15-30	413.95	89.02	637.39
	30-45	338.69	101.60	638.46
	Range	338.69-492.35	89.02-102.29	637.39-719.16
	Mean	415.00	97.64	665.00
Coffee multistore-yed system	0-15	495.49	91.64	579.10
	15-30	417.09	87.26	545.99
	30-45	319.87	90.50	552.26
	Range	319.87-495.49	87.26-91.64	545.99-579.10
	Mean	410.82	89.796	559.12
Agriculture mono crop-ping system	0-15	323.01	78.52	417.18
	15-30	282.24	62.68	398.72
	30-45	185.02	53.46	322.30
	Range	185.02-323.01	53.46-78.52	322.30-417.18
	Mean	263.42	64.89	379.40
Agriculture mixed cropping system	0-15	348.10	83.99	524.78
	15-30	266.56	76.86	502.95
	30-45	197.57	57.11	475.48
	Range	197.57-348.10	57.11-83.99	475.48-524.78
	Mean	270.74	72.65	501.07
CD (P = 0.05)		11.55	5.55	18.46
SEm ±		7.147	1.760	8.531
CV (%)		349.30	177.00	558.00

different types. Considering the effects of land use types, the highest average (97.64 and 665.60 kg ha^{-1}) available phosphorous and potassium was recorded on the pure coffee plantations and the lowest (64.89 and 379.40 kg ha^{-1}) was recorded on the agriculture monocropping respectively (Table 3). Considering the interaction effect of land use types with soil depth, the similar trend was followed in land use types but higher phosphorous and potassium recorded in surface layer compared to subsurface layer (Table 3). Aytenew and Kibret (2016) and Chemada *et al.* (2017) reported that the higher available phosphorous was obtained in forest land at both surface and subsurface soil layer. Relatively the high content of available phosphorous in the forest land could be due to the high content of soil OM resulting in the release of organic phosphorus thereby enhances available P under forest land. Similarly, this result is in agreement with the findings of Abad *et al.* (2014) who reported that the available P was high in forest land compared to pasture land and cultivated land at 0-30 cm soil depth.

The study area has low bulk density, which is indicated the higher soil OM. The soil pH ranged in between 5.46 to 6.35 in forest lands and cultivated respectively. The highest mean value EC ranged in between 0.322 to 0.633 d Sm^{-1}. The higher SOC and available N were recorded in the forest land while the lower was found in the agriculture land use. Highest per cent carbon loss compare to natural forest was observed in agriculture based land use systems compared to tree based land use systems. The higher SOC and available N was observed on the surface soil layer and it is decreasing with increasing soil depth. The available P_2O_5 and K_2O contents were higher in pure coffee plantations compared to agriculture land use. These results demonstrate that conversion of natural forest into different land use systems adversely affect the soil properties.

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