Annals of Plant and Soil Research 25 (1): 110-119 (2023)
https://doi.org/10.47815/apsr.2023.10243

Chemical properties of soil in forest and non-forest land use in Bangalore rural forest division, Karnataka

M.V. DURAI*, ABHISHEK GODI, N.RAVI, VAJUHULLA AND A.G. KARTIK

Institute of Wood Science and Technology, Malleswaram, Bangalore – 560 003 (Karnataka)

Received: December, 2022; Revised accepted, February, 2023

ABSTRACT

The study was conducted to know the variations in chemical properties of soil in forest and non-forest land uses in Bangalore-rural forest division, Karnataka. The soil samples were collected from 8 non-forest land uses and 6 forest land uses from three depths viz., 0-30, 30-60, and 60-90 cm. The results showed that non-forest land use soils recorded significantly higher mean values of pH (6.53), EC (0.21dSm^{-1}), K (243.25 kgha^{-1}), Mg (1.55 C mol p^{+} kg^{-1}), Fe (21.31 ppm), whereas forest soils characterized by higher OC% (1.37), N (495.3 kgha^{-1}), P (10.15 kgha^{-1}), Ca (12.90 C mol p^{+} kg^{-1}), S (77.32 mgkg^{-1}), Mn (3.05), Zn (0.06 ppm), Cu (3.25 ppm) at surface layer. And in sub-surface layer, the non-forest land use showed higher mean values in pH (6.58), P (10.90 kgha^{-1}), K (246.75 kgha^{-1}), Mg (1.12±1.06 C mol p^{+} kg^{-1}), Zn (0.08 ppm), whereas forest land use showed EC (0.21 dSm^{-1}), OC % (1.71), N (614.9 kgha^{-1}), Ca (13.85 C mol p^{+} kg^{-1}), S (74.36 mgkg^{-1}) Fe (22.95 ppm), Mn (3.05 ppm), Cu (2.15 ppm). At bottom layers the non-forest land use showed higher mean values in EC (0.23 dSm^{-1}), P (7.96 kgha^{-1}), K (187.25 kgha^{-1}), Mg (1.76 C mol p^{+} kg^{-1}), Mn (2.12 ppm) and Cu (2.6 ppm). Whereas forest land use showed pH (6.6), OC% (1.5), N (551 kgha^{-1}), Ca (13.25 C mol p^{+} kg^{-1}), S (41.4 mgkg^{-1}), Fe (22.29 ppm), Zn (0.07 ppm). Thus, the chemical properties of soils varied with vegetation type, species composition and management practices.

Keywords: Soil, properties, forest, land use, carbon, nutrient

INTRODUCTION

Soil and vegetation are mutually associated with each other and influence each other (Jones *et al.* 1994; Van Breemen and Finzi, 1998). Forest structure and its composition affect the properties of soil to a great extent (Mishra *et al.* 2013; Sharma *et al.* 2009) and vice-versa. The species distributions affect the soils and habitat factors (Mishra *et al.* 2017; Sharma *et al.* 2009). The physical, chemical and biological properties of soils are influenced by vegetation and management practices (Yifru and Taye, 2011; Getahun *et al,* 2014). For example, land cover affects soil particle distribution, bulk density, aggregate formation (Lu *et al.* 2002; Armenteras *et al.* 2006; Biro *et al.* 2013), distribution of carbon, nitrogen including other nutrients, microbial activity and biomass mineralization in soils (Lemeneh, 2004; Han *et al.* 2018). The loss of vegetation cover affects the nutrient status of soil and consequently leads to the loss of health (Hajabbasi *et al.* 1997; Moran *et al.* 2000; Clark, 2012). Anthropogenic activities viz., trampling, illicit felling and grazing affect significantly the litter input, carbon stabilization, and nutrient turnover (Six *et al.* 2002; Haile *et al.* 2014; Oraon *et al.* 2018). Plants, especially understorey vegetation influence mineral weathering and soil fertility (Lukina *et al.* 2019). Earlier studies indicated that tree species abundance is co-related with the physicochemical status of soil in many areas (Mata *et al.* 2011; Nizam *et al.* 2006; Teixeira *et al.* 2008). The physicochemical properties of the soil also influence the seed production of plants species (Whitmore, 1984). Clay rich soil supports the inland forest whereas the seasonal flood forest and the riverine forest are found in clay loam and silty clay soils (Khairil *et al.* 2014). The land use pattern also significantly influences soil organic carbon and total nitrogen (Bolin and Sukumar, 2000; Zajicova and Chuman, 2019). Soils under Acacia forest land had relatively higher content of organic matter, total nitrogen, exchangeable cations, and CEC than that of vegetable and fallow sites. Soils under vegetable land had higher amount of available phosphorus than that of other two land use types (Akhtaruzzaman *et al.* 2020). Organic matter content is low in the inland, seasonal and riverine forests and there is no significant

*Corresponding author email.-duraimv@gmail.com

difference among the forest types. Further, it is reported that there were significant differences between available P, available K, cations such as K^+, Ca^{2+}, Mg^{2+} and EC among the three types of forest (Khairil *et al.* 2014). Although, a number of studies have been conducted on soil distributions and soil properties under different land use systems in different countries, little information on soil properties under forest and non-forest land use is available in India. Therefore, the objective of this study was to determine the variations in chemical properties of the soil and its nutrient content under forest and non-forest land use in the Bangalore forest division, Karnataka.

MATERIALS AND METHODS

The study was conducted in forest and non-forest land use systems in Bangalore forest division, Karnataka, India. The study area includes two land uses viz., forest and non-forest. The Bengaluru rural forest division has a dry-tropical Savanna climate and is characterized by four main seasons viz., cold weather season, hot weather season, southwest monsoon, and northeast monsoon seasons. The mean annual rainfall in the division is 793mm. The average temperature is 38°C (Max.) and 15°C (Min). In the present study, three forest types viz., dry deciduous scrub (5/DS1), southern thorn scrub (6A/DS1) and southern thorn forest (6A/C1) were considered. Non-forest lands adjoining to forest area were selected for comparison. Non-forest land use includes non-forest (NF, canopy density: No vegetation), scrub forest (SF, canopy density: <10%) and open forest (OF, canopy density: 10-40%). The basic information of forest and non-forest land uses is given in Table 1 and 2, respectively. Total 14 sample points were chosen for soil sample collection based on proportional to area of the land use using grid-based approach (5x5km). The grid points were prepared with help of satellite imagery of forest vegetation. The geo-coordinates, forest type, species composition, elevation, aspect, hill shade and forest soil class of forest land use and non-forest land uses are given in Table 1 and 2, respectively. Prior to soil sampling, the litter and grasses were removed from an area of 50 x 50 cm at each sampling point. Then, a pit was made up to desired depth manually using crowbar and spade. About 500g of representative soil samples were collected by scraping soil from any three sides of the pit from the bottom at three depths viz., 0-30 (surface), 30-60 (sub-surface) and 60-90 cm (deep layer). After removing gravel, soil samples were packed in cloth bags (1kg capacity) with proper labels.

Table 1: Details of sample points of forest land uses

Forest type and (Species composition)	Forest class	Sample point location (Lat, Long)	Slope	Aspect	Elevation	Hill shade	FAO soil
Dry Deciduous Scrub 5/DS1							
Acacia leucophloea, Albiziaamara, Dalbergiapaniculata, Azadirachtaindica	NF	13°22'39.144"N 77°31'31.852" E	11	309	912	192	Ne53-2ab
Euphorbia antiquorum, Pterolobiumindicum,Cassia fistula, Lantana camera, Opuntiadillenii	SF	12°59'3.372"N 77°51'18.612" E	5	160	906	180	Ne53-2ab
Southern Thorn Scrub 6A/DS1							
Albiziaamara, Chloroxylonswietenia, Wrightiatinctoria, Randiadumetorum	NF	13°16'17.364"N 77°45'1.152" E	7	107	908	165	Ne53-2ab
Albiziaamara, Chloroxylonswietenia, Wrightiatinctoria, Randiadumetorum Elaeodendron, Pongamia, Cassia fistula, PhyllanthusemblicaDendrocalamusstrictus	NF	13°10'5.232"N 77°51'35.316" E	7	176	934	167	Ne53-2ab
Southern Thorn Forest 6A/C1							
Acacia catechu, Acacia leucophloea, Acacia militia, Flacourtiaindica, Euphorbia nivulia, Chloroxylonswietenia,	NF	13°4'22.008"N 77°54'21.996" E	19	120	932	124	Ne53-2ab
Acacia catechu, Acacia leucophloea, Ixoraarborea, Strychnospotatorum, Cassia auriculata, Dodoneaviscosa,	NF	13°4'22.008"N 77°54'21.996" E	19	120	932	124	Ne53-2ab

The collected soil samples were air-dried at room temperature, crushed and passed through a 2mm diameter sieve for analysis.Soil pH was measured in soil-water suspension (1:2.5) using pH-meter (Singh *et al.* 2005). Estimation of soil Organic carbon (OC) and Organic matter was done by the wet-oxidation method of Walkley-Black (1934). Available nitrogen was estimated by alkaline permanganate method (Subbiah and Asija, 1956). Available phosphorus was determined by Bray's P-1(Bray and Kurtz, 1945) and potassium, calcium, magnesium were estimated by neutral normal ammonium acetate method (Stanford and English, 1949). Available sulphur was determined by turbidimetric method (Chesnin and Yien, 1950) and DTPA extractable Fe, Mn, Zn, and Cu were determined by method given by Lindsay and Norvell, 1978.

Table 2: Details of sample points of non-forest land uses

Non-Forest (Species composition)	Forest class	Sample point location (Lat, Long)	Slope	Aspect	Elevation	Hill shade	FAO soil
Anogeissuslatifolia, Albiziaamara, Flacourtiaindica, Euphorbia nivulia, Chloroxylonswietenia, Ixoraarborea	OF	13°25'47.316"N 77°24'29.52" E	13	314	837	215	Lc75-2b
Strychnospotatorum, Cassia auriculata, Dodoneaviscosa,	OF	13°23'13.884"N 77°28'21.936"E	20	343	895	230	Ne53-2ab
Cocosnucifera, Areca catechu, Azadirachtaindica, Bambusabambu	NF	13°17'31.56"N 77°30'25.668"E	6	274	889	196	Ne53-2ab
Tamarindusindia, Eucalyptus sp., Azadirachtaindica, Terminaliatomentosa, Syzygiumcuminii, Lantana camera, Cocosnucifera	NF	13°14'22.776"N 77°40'46.956"E	2	36	882	173	Ne53-2ab
Acacia catechu, Chloroxylonswietenia, Ixoraarborea.	OF	13°11'14.064"N 77°48'30.852"E	5	254	879	163	Ne53-2ab
Cocosnucifera, Areca catechu, silver oak, Mangiferaindica, lantana camera, Lycopersiconesculentum, solanummelongena	NF	13°10'3.252"N 77°14'57.732"E	6	169	918	160	I-Lc-2bc
Cocosnucifera, Areca catechu, solanummelongena	NF	13°7'26.364"N 77°19'17.904"E	4	334	860	179	Ne53-2ab
Tamarindusindia, Zizyphus, Canthium, Albizia, Wrightiatinctoria, Diospyrosferonia, Acacia lemonia.	OF	13°15'32.832"N 77°25'53.292"E	1	66	893	179	Ne53-2ab

RESULTS AND DISCUSSION

Chemical properties of surface soil in forest and non-forest land use

Soil pH, EC and organic carbon content

The data on soil pH, EC and OC of soil is given in Table 3. The pH value of surface soil of non-forest land use in Bengaluru rural was neutral (6.53 ± 0.47) and slightly higher than that of forest soils (6.31 ± 0.55). The soils of forest and non-forest are acidic. High values of soil pH in different layers of forest land might be due to more input of bases through nutrient recycling. The variation in the soil pH among different cropping systems may be due to variation in rainfall within the zone, topographic and management practices *(*Ananthnarayana and Ravi, 1997*).* The pH ranged from 4.15-6.4 in agriculture soils and from 3.86- 5.64 in forest soils (Himalini and Razia, 2019). The agriculture soil was slightly acidic when compared to forest soil (Kimmins, 1997; Himalini and Razia, 2019).

Moreover, forest covers also play an effective role in protecting soil nutrients and bases from leaching loss (Chen and Guo, 2008). The EC, total soluble salt content in soil was very low in forest land use (0.1 ± 0.05 dSm^{-1}) when compared to the non-forest land use (0.21± 0.12 dSm^{-1}). The EC follows same trend as soil pH. The organic carbon was found significantly higher in forest land use (1.37 ± 0.05%) when compared to non-forest land use (0.64 ± 0.33%). The electrical conductivity of both the land uses was found normal (<1). The lesser the EC value, low will be the salinity value of soil and vice-versa. The low EC indicate that the soluble salts were leached out of soil under high rainfall area; consequently, there was no salt accumulation in soils (Rao, 1992). Forest litter contributed to a higher amount of organic matter in *Acacia* forest site compared to other sites under study (6A/C1-southern tropical thorn forest). The higher organic carbon content in the sub-surface layer of non-forest areas might be attributed to the higher mixing of soils as the soils are under tillage operation. It is evident to the fact that these soils had higher soil organic carbon content. The accumulation of soil organic matter is a function of the amount of plant, animal and microbial inputs received by soil in the past (Brady and Weill, 1996) and the rate of biomass decays. The present results revealed that variations in organic carbon along soil depths were due to climate, land cover, soil texture, and soil order. Organic matter content was found higher in forest soils when compared to other land uses in India. The present findings are consistent with that of Batjes (2016) and Panwar *et al.* (2011).

Table 3: Chemical properties of forest and non-forest soils at surface (Mean ± SD)

Forest Type	pH (1:2.5)	EC (dSm^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Non-Forest	6.53±0.47	0.21 ±0.12	0.64 ± 0.33	233.4±120.9	6.98±11.02	243.25±111.98
5/DS1	6.31 ±0.55	0.16 ±0.07	0.76±0.23	282.5±71.42	3.27±2.05	182± 59.39
6A/DS1	5.3 ± 0	0.1 ± 0.05	1.37±0.05	495.3±17.96	10.15±8.28	140± 19.79
6A/C1	6.12 ± 0.11	0.14 ±0.00	0.86±0.41	311.9±148.6	6.33±5.32	161± 9.89

Available N, P and K

The data on available N, P and K of forest and non-forest land uses is presented in Table 3. The data revealed that available N and P content recorded lower concentrations in non-forest land use areas (233.4 ± 120.9 and 6.98 ± 11.02 $kgha^{-1}$) when compared to forest land use areas (495.3 ± 8.28 and 10.15 ± 8.28 $kgha^{-1}$). This variation in availability of N and P concentrations follows the same trend as OC %. The available K was higher in non-forest land use (243.25 ± 111.98 $kgha^{-1}$) when compared to forest land use (182.00 ± 59.39 kg ha^{-1}). The available content of N, P and K was medium to low in both the land use systems. The medium status of available nitrogen and low status of available P in acid soils may be due to recycling of biomass (leaf litter and residue and addition of manures). Variation in available N in different land use along the depths of soil may be attributed to soil organic matter and total-N contents. The SOC content was highly correlated with soil N and P content in acid soils (Korikanthimath *et al. 2002).* According to (Salmon, 1964), the K content in highly weathered soils of the tropical regions is similar to that in the parent rock and primary materials in the sand and silt fractions. But after continued weathering and leaching, the K content in all particle size fractions became low. It is generally reported that soils of temperate regions have higher K content than the more weathered acid soils of the humid tropics (Schroeder, 1978). Further, in horticultural systems higher accumulation of potassium was due to excess application of fertilizers and manures (Chang *et al.* 2008). Macro nutrients were found to be higher in agricultural soil than forest soil samples in Kodaikanal region (Himalini and Razia, 2019).

Exchangeable Ca, Mg and S

The data (Table 4) revealed that exchangeable Ca^{2+} did not vary significantly in both the land use systems, forest land use (12.90 ± 8.98 C mol p^{+} kg^{-1}) and non-forest land use (12.07 ± 8.22 C mol p^{+} kg^{-1}). Mg varied significantly along the non-forest and forest land use (1.55 ± 1.0 and 1.47 ± 0.1 C mol p^{+} kg^{-1}). The sulphur content was significantly higher in forest land use (77.32 ± 5.55 $mgkg^{-1}$) when compared to non-forest land use (27.12 ± 27.09 $mgkg^{-1}$). Exchangeable calcium did not vary significantly in both forest and non-forest areas. Marschner (1995) found very high amount of Ca in both the systems. Exchangeable Ca^{2+} was the dominant cation followed by Mg^{2+}, and K^{+} in the soils of both land use systems. These results are in conformity with findings of (Akhtaruzzaman *et al.* 2020). Magnesium also showed similar trend as Ca^{2+}. Magnesium concentrations in the deeper layer of soil are low when compared to upper layer (Lukina *et al.* 2019). The results of the present study are consistent with that of Lukina et al (2019). Available sulphur content varied significantly between forest and non-forest land uses and high sulphur content was found in forest areas (Table 4). Acid soils of Manipur had inorganic sulfur content ranged between 10-70 ppm and the higher available sulphur content was attributed to higher organic content (Singh *et al.* 2006; Kuntoji *et al.* 2020).

Table 4: Chemical properties of forest and non-forest soils at surface layer (Mean ± SD)

Forest Type	Ca C mol (p+) kg^{-1}	Mg C mol (p+) kg^{-1}	S $mgkg^{-1}$	Fe ppm	Mn ppm	Zn ppm	Cu ppm
Non-Forest	12.07±8.22	1.55±1	27.12±27.09	21.31±13.53	2.15±2.53	0.03±0.02	1.93±1.16
5/DS1	5.13±0.1	1±1.22	10.77±4.21	11.58±7.52	0.57±0.61	0.04±0.0	3.25±0.64
6A/DS1	12.9±8.46	0.74±0.79	77.32±5.55	23.1±6.51	0.15±0.07	0.06±0.04	2.2±0.85
6A/C1	12.69±10.7	1.47±0.1	68.76±21.19	16.5±0.28	3.05±0.21	0.04±0.05	2.2±1.84

Micronutrients (Mn, Zn, Cu and Fe)

The content of Mn, Zn and Cu was 3.05 ± 0.21, 0.08 ± 0.09 and 3.25 ± 0.64 ppm and 1.15 ± 0.27, 0.03 ± 0.02 and 1.93 ± 1.96 ppm in forest and non-forest land uses, respectively (Table 4). The iron content showed significantly higher in non-forest land use (22.95 ± 3.98 ppm) when compared to forest areas (17.04 ± 7.27 ppm). The content of micronutrients, Fe, Mn, Zn and Cu, was found higher than that of critical level in both land uses. This might be attributed primarily due to lower soil pH as decrease of pH is associated with increased solubility of these micronutrients (Brady and Weil, 2002). The micro-nutrients were found to be higher in agriculture soil than forest soil samples in Kodaikanal soil (Himalini and Razia, 2019).

Chemical properties of sub-surface soil in forest and non-forest land use

Soil pH, EC and OC

The data on pH, EC and OC of sub-surface soil of forest and non-forest land uses is given in Table 5. The pH value of the soil in non-forest land use was higher (6.58 ± 0.57) than the forest land use (5.87 ± 0.97). The EC was significantly higher in the forest land use (0.21 ± 0.05 dSm^{-1}) when compared to the non-forest land use (0.19 ± 0.09 dSm^{-1}). The organic carbon was found significantly higher in forest land use (1.71 ± 0.54%) when compared to non-forest land use (0.61 ± 0.21%).

Tree species are one of the many factors that influence soil C and N input and output (Devi, 2021). The effect of tree species depends on differences in soil conditions, such as parent material and land use (Vesterdal *et al.* 2008). Forest soil is a much more important C sink worldwide than living forest biomass, with concentrations two to four times higher in the upper 30 cm, and three to six times higher in the upper 50 cm (Calvode *et al.* 2020). Mixed forest stands recorded an average SOC of 4.62 ± 2.08 % (Devi, 2021). Forests of different tree species differ in litter quality and root exudates, resulting in variation in soil properties, which may affect the soil microbial community (Chandra *et al.*2016). The SOC dynamics also differ due to variations in local vegetation types (Gruba *et al.* 2015).

Table 5: Chemical properties of forest and non-forest soils at the sub-surface layer (Mean ± SD)

Forest Type	pH (1:2.5)	EC dSm^{-1}	OC (%)	N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}
Non-Forest	6.58 ±0.57	0.19±0.09	0.61±0.21	219.2±75.89	10.9±20	246.75±175.97
5/DS1	6.4±0.28	0.16±0.08	1.7±1.21	612.2±435.8	0.37±0.38	133±9.9
6A/DS1	5.87±0.97	0.1±0.05	1.71±0.54	614.9±202.4	9.13±9.72	119±9.9
6A/C1	5.87±1.6	0.21±0.05	0.81±0.16	291.9±59.26	1.555±0.53	154±19.8

Available N, P and K

Available N content recorded lower concentrations in non-forest land use areas (219.2 ± 75.9 kgha^{-1}) when compared to forest land use areas (614.9 ± 202.4 kgha^{-1}) (Table 5). The variations in the nitrogen content are due to soil organic carbon and total nitrogen content. Soil available P and K contents were higher in non-forest land use (10.90 ± 20.00 and 246.75 ± 175.94 kgha^{-1}) when compared with forest land use (1.55 ± 0.53 and 154 ± 19.80 kgha^{-1}). The P and K significantly vary along the two land use systems (Table 5). The available N content was higher in forest land use. However, P and K were medium to low in both the land use systems.

Exchangeable Ca, Mg and S

Exchangeable Mg did not vary significantly in both the land use systems, forest land use (1.12 ± 1.08 C mol p$^+$ kg^{-1}) and non-forest land use (1.11 ± 1.30 C mol p$^+$ kg^{-1}) (Table 6). The Ca content recorded higher mean values in forest land use (13.15 ± 10.90 C mol p$^+$ kg^{-1}) when compared to non-forest land use (12.03 ± 9.18 C mol p$^+$ kg^{-1}). The sulphur content was significantly higher in forest land use (74.36 ± 4.44 mgkg^{-1}) (Table 6) when compared to non-forest land use (27.12 ± 27.09 mgkg^{-1})

Table 6: Chemical properties of forest and non-forest soils at the sub-surface layer (Mean ± SD)

Forest Type	Ca C mol (p+) kg^{-1}	Mg C mol (p+) kg^{-1}	S mgkg^{-1}	Fe ppm	Mn ppm	Zn ppm	Cu ppm
Non-Forest	12.03 ±9.18	1.12±1.06	23.94±25.01	17.04±7.27	1.15±0.57	0.08±0.09	1.14±0.99
5/DS1	5.62±2.70	0.29±0.27	39.2±41.30	13.7±13.01	1.75±0.49	0.07±0.01	1.46±2.04
6A/DS1	13.85±10.90	1.11±1.30	74.36±4.44	22.95±3.18	3.05±2.19	0.04±0.04	0.84±0.51
6A/C1	5.91±1.58	0.64±0.59	34.63±43.31	8.48±7.25	2.05±1.77	0.02±0.01	2.15±2.76

Micronutrients (Mn, Zn, Cu and Fe)

The data on Mn, Zn, Cu and Feof sub-surface soil of forest and non-forest land uses is given in Table 6.DTPA extractable Fe, Mn and Cu recorded higher concentrations in forest areas (22.95 ± 3.18, 3.05 ± 2.19, and 2.15 ± 2.76 ppm) when compared to non-forest areas (17.04 ± 7.27, 1.15 ± 0.37, and 1.14 ± 0.99 ppm). The Zinc content was significantly higher in non-forest land use (0.08 ± 0.09 ppm) when compared to forest areas (0.04 ± 0.04 ppm). The content of DTPA Fe, Mn and Cu which is far higher than critical level might be attributed primarily lower soil pH.

Chemical properties of bottom layer soil in forest and non-forest land use

Soil pH, EC and OC

The measure of Soil pH is the main parameter that helps in the identification of chemical nature of soil (Shalini *et al.* 2003). The pH value of soil in non-forest land use (6.42 ± 0.33) was higher than the forest land use (6.62 ± 0.11) (Table 7). Conductivity as a measure of salinity status of soil, total soluble salt content in soil was very low in forest land use (0.11± 0.04 dSm^{-1}) when compared to the non-forest land use (0.23± 0.12 dSm^{-1}). The Organic carbon was found significantly higher in forest land use (1.5 ± 1.27 %) (Table 7) when compared to non-forest land use (0.87 ± 0.49 %).

Available N, P and K

Available N content recorded lower concentrations in non-forest land use areas (319.4 ± 176.9 kgha^{-1}) when compared to forest land use areas (551.3 ± 451.1kgha^{-1}) (Table 7). The available P and K was higher in non-forest land use (7.96 ± 11.99 and 187.25 ± 91.63 kgha^{-1}) when compared to forest land use (4.4 ± 4.86 and 126 ± 0 kgha^{-1}).

Exchangeable Ca, Mg and S

The data on Ca, Mg and S of bottom layer soil of forest and non-forest land use is given in Table 8. Exchangeable Ca did not vary significantly in both the land use systems (forest land use:13.25 ± 9.65; non-forest land use:

13.12 ± 7.59 C mol p^+ kg^{-1}). The Mg content varied significantly along the non-forest and forest land use (1.76 ± 1.61 and 0.86 ± 0.28 C mol p^+ kg^{-1}). The sulphur content was significantly higher in forest land use (41.4. ± 44.41 $mgkg^{-1}$) when compared to non-forest land use (28.49 ± 27.71 $mgkg^{-1}$).

Table 7: Chemical properties of forest and non-forest soils at bottom layer (Mean ± SD)

Forest Type	pH (1:2.5)	EC dSm^{-1}	OC (%)	N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}
Non-Forest	6.42±0.33	0.23±0.12	0.87±0.49	319.4± 176.9	7.96±11.99	187.3±91.6
5/DS1	6.62±0.11	0.13±0.01	1.5±1.27	551± 451.1	1.68±0.96	126±39.6
6A/DS1	6.35±0.92	0.04	0.94±0.52	339.3± 187.3	2.79±1.06	112±19.8
6A/C1	5.88±0.74	0.22±0.11	1.21±0.41	453.6±169.4	4.4±4.86	126±0.00

Micronutrients (Mn, Zn, Cu and Fe)

Available Fe and Zn recorded higher concentrations in forest areas (22.29 ± 3.69 and 0.07 ± 0.08 ppm) when compared to non-forest areas (18.53 ± 9.42 and 0.04 ± 0.01 ppm) (Table 8). The Mn and Cu content were significantly higher in non-forest land use (2.12 ± 1.62 and 2.6 ± 0.96 ppm) when compared to forest areas (1.43 ± 0.24 and 1.8 ± 0.85 ppm).

From this study, it is concluded that chemical properties of forest and non-forest land uses vary with slope, aspect ratio, hill shade, elevation, vegetation type and species composition. The pH of forest soils was found slightly acidic in nature when compare with non-forest soils. Forest soils had higher organic carbon than that of non-forest soils. Available N was found higher in forest soils whereas P and K content were maximum in non-forest soils. The content of secondary nutrients (Ca, Mg and S) did not show any difference between forest and non-forest soils. Micronutrients (Fe, Mn, Zn and Cu) content was found higher in non-forest soils when compared with forest land use. In order to improve and maintain the soil fertility and productivity in forest and non-forest land uses, measures such as incorporation of forest litter and organic manures, soil and water conservation measures, control of forest fire and excessive grazing may be considered.

Table 8: Chemical properties of forest and non-forest soils at bottom layer (Mean ± SD)

Forest Type	Ca C mol (p+) kg^{-1}	Mg C mol (p+) kg^{-1}	S ppm	Fe ppm	Mn ppm	Zn ppm	Cu ppm
Non-Forest	13.12±7.59	1.76±1.61	28.49±27.71	18.53±9.42	2.12±1.62	0.04±0.01	2.6±0.96
5/DS1	6.99±2.08	0.39±0.34	35.1±37.76	22.29±3.69	1.05±0.49	0.05±0.01	0.5±0.62
6A/DS1	7.74±2.02	0.38±0.49	41.4±44.41	5.98±4.56	1.43±0.24	0.07±0.08	0.7±0.28
6A/C1	13.25±9.65	0.86±0.28	7.81±5.74	15.35±4.45	1±1.13	0.04±0.05	1.8±0.85

ACKNOWLEDGEMENTS

The authors acknowledge the financial support of the Governing Body of National Authority, CAMPA for funding the research project AICRP project “Preparation of forest soil health cards under different forest vegetations in all the forest divisions of India”. We, convey our sincere thanks to Dr. S.D. Pathak, APCCF (Research), DFO, Forest Range Officers, and other Forest Field staffs (Bangalore- Rural Forest Division), Karnataka Forest Department for their kind help and support for collection of guidance, field data and soil samples throughout study. We, also, extend our gratitude to Dr. M. P. Singh, Director, IWST, Bangalore, Shri. V.S.Shettappanavar, GCR, IWST and Dr. A.N. Arun Kumar, Head, SFM, IWST, Bangalore for support and encouragement.

REFERENCES

Armenteras, D., Rudas. G., Rodriguez, N., Sua, S., Romero, M. (2006) Patterns and causes of deforestation in the Colombian Amazon. *Ecological Indicators* **6**: 353-368.

Ananthanarayanaya, R., and Ravi, M.V. (1997) Nature of Soil acidity of coffee growing soils of Karnataka. *Journal of Indian society of soil science* **45**: 384-385.

Akhtaruzzaman, Md., Sajal Roy., Muhammad Sher Mahmud. And Shormin, T. (2020) Soil Properties Under Different Vegetation Types in Chittagong University Campus, Bangladesh. *Journal of Forest and Environmental Science* **2:** 132-142.

Batjes, N.H. (2016) Harmonized soil profile data for applications at global and continental scales: updates to the WISE database. *Soil Use and Management* **25**:124-127.

Bray, R.H. and Kurtz, L.T. (1945) Determination of total, organic, and available forms of phosphorus in soils. *Soil science* **59**:39-45.

Bolin, B. and Sukumar, R. (2000) Global perspective. In: Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H., Verardo, D.J. & Dokken, D.J. (eds). Land Use, Land-use Change, and Forestry. A Special Report of the IPCC, Cambridge University Press, Cambridge, UK, 23-51.

Biro, K., Pradhan B., Buchroithner, M., Makeschin, F. (2013) Land use/land cover change analysis and its impact on soil properties in the northern part of Gadarif region, Sudan. *Land Degradation and Development* **24**: 90-102.

Brady, N.C., and R.R. Weil. (2002) The nature and properties of soils. 13th Ed, Pearson Education, Inc., New Jersey, USA 960p.

Brady, N.C., and R. R, Weil. (1996) The nature and properties of soils. 13th Ed, Pearson Education, Inc., New Jersey, USA 960p.

Calvode, A.R., Luis, E., Febrero-Bande, M., Galinanes, J., Macias, F., Ortiz, R. and Casas, F. (2020) Soil organic carbon in peninsular Spain: Influence of environmental factors and spatial distribution. *Geoderma* **370**:114-365.

Chandra, L.R., Gupta, S., Pande, V. and Singh, N. (2016) Impact of forest vegetation on soil. Characteristics: a correlation between soil biological and physic-chemical properties. *3 Biotech* **6**:188.

Clark, M.N. (2012) Deforestation in Madagascar: consequences of population growth and unsustainable agricultural processes. *Global Majority E- Journal* **3**: 61-71.

Chesnin, L. and Yien, C.H. (1951) Turbidimetric determination of available sulphate. *Soil science society of American proceedings* **15**:149-151.

Chen, J. and Guo, C. (2008) Ecosystem ecology research trends. Nova Science Publishers, New York, NY, pp 308.

Chang, E.H., Chung, R.S and Wang, F.N. (2008) Effect of different types of organic fertilizers on the chemical properties and enzymatic activities of an Oxisol under intensive cultivation of vegetables for 4 years. *Soil science and plant nutrition* **54**:587-599.

Devi, A.S. (2021) Influence of trees and associated variables on soil organic carbon: a review. *Journal of Ecology and Environment* **5**: 1-14.

Getahun, Y., Zebene, A., Solomon, Z. (2014) Wood production and management of woody species in home gardens agroforestry: the case of smallholder farmers in Gimbo district, south west Ethiopia. *International journal of Natural Science and Research* **2**: 278-283.

Gruba, P., Socha, J., Blonska, E. and Lasota, J. (2015) Effect of variable soil texture metal saturation of soil organic matter (SOM) and tree species composition on spatial distribution of SOM in forests soils in Poland. *Science of total environment*, 90–100.

Haile, G., Lemenhi, M., Itanna, F. and Senbeta, F. (2014) Impacts of land uses changes on soil fertility, carbon and nitrogen stock under smallholder farmers in central highlands of Ethiopia: implication for sustainable agricultural landscape management around Butajira area. *New York Science Journal* **7**: 27-44.

Hajabbasi, M.A., Jalalian, A. and Karimzadeh, H.R. (1997) Deforestation effects on soil physical and chemical properties, Lordegan, Iran. *Plant and Soil* **190:** 301-308.

Han, X., Gao, G., Chang, R., Li, Z., Ma, Y., Wang, S., Wang, C., Lu, Y. and Fu, B. (2018) Changes in soil organic and inorganic carbon stocks in deep profiles following cropland abandonment along a precipitation gradient across the Loess Plateau of China. *Agriculture, Ecosystem and Environment* **258**: 1-13.

Himalini, S. and Razia, M. (2019) Nutrient Analysis of Agriculture and Forest Soil in High Altitude of Kodaikanal. *Nature Environment and Pollution Technology* **2**: 619-622.

Jones, C.G., Lawton, J.H. and Shachak, M. (1994) Organisms as ecosystem engineers. *Oikos* **69**:373–386.

Thi, Dinh, Kim Hao and Shima, Kazuta (2022) Effects of Forest Reclamation methods on soil physiochemical properties in North central Vietnam. *Research on Crops* **1**:110-118.

Korikanthimath, V. S., Gaddi, A. V., AnkeGowda, S. J. and Govardhan Rao (2002) Soil fertility evaluation in plantation belt of Kodagu district, Karnataka. *Journal of Medicinal and Aromatic Plant Sciences* **24**: 401-409.

Kuntoji, Altaf.,Subramanyappa, C.T., Chamegowda, T.C., Sathish A, Ramanamurthy, V. and Mallesha, B.C. (2020) Studies on soil physico-chemical and biological properties and evaluation of nutrient index for soil fertility along rural-urban interface of southern transect of Bengaluru. *International journal of chemical studies* **9** (1): 2267-2275.

Karim, A. and Khan, D.H. (1955) Soils of the Nanakhi series, East Pakistan: I. Morphology, textural separates, and exchangeable cations. *Soil Science* **80**: 139-145.

Khairil, M., Juliana, WA. Wan. andNizam, A.S. (2014) Adaphic Influences on tree species composition and community structure in a tropical watershed forest in peninsular Malaysia. *Journal of Tropical Forest Science* **2**:284-294.

Kimmins, J.P. (1997) Forest Ecology. 2nd Edition, Prentice Hall, Upper Saddle River, 596 p.

Lu, D., Moran, E. and Mausel, P. (2002) Linking Amazonian secondary succession forest growth to soil properties. *Land Degradation and Development* **13**: 331-343.

Lemenih, M. (2004) Effects of Land Use Changes on Soil Quality and Native Flora Degradation and Restoration in the Highlands of Ethiopia. Doctoral Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden. (In English).

Lindsay, W.L. and Norwell, W.A. (1978) Development of DTPA soil test for Zn, Fe, Mn and Cu. *Science society of America Journal* **42**: 421-428.

Lukina, N, V., Tikhonova, E.V., Danilova, M.V., Bakhmet, O.N., Kryshen, A.M., Tebenkova, D.N., Kuznetsova, A. L., (2019) Associations between forest vegetation and the fertility of soil organic horizons in north western Russia. *Forest Ecosystems* **6**:34.

Marschner, H. (1995) Mineral Nutrition of Higher Plants. Academic Press. London, p. 889.

Moran, E.F., Brondizio, E.S., Tucker, J.M., Silva-Forsberg, M.C. D., McCracken, S and Falesi, I. (2000) Effects of soil fertility and land-use on forest succession in Amazônia. *Forest Ecology and Management* **139**: 93-108.

Mishra, A, K., Behera., S, K., Singh, K., Sahu, N., Bajpai, O., Kumar, A., Mishra, R. M., Chaudhary, L. B. and Singh, B. (2013) Relation of Forest Structure and Soil Properties in Natural, Rehabilitated and Degraded Forest. *Journal of Biodiversity Management and Forestry* 2:4.

Mishra, A, K., Singh, K., Behera, S. K.., Chaudhary, L. B., Singh, B. and Mishra, R. M. (2017) Soil properties in response to different plant community structures in Tropical Moist Deciduous Forest from Northern India. *Climate Change and Environmental Sustainability* **5**: 66–74.

Mata, D, I., Moreno-Casasola, P., Madero-Vega, C., Castillo, Campos, G. and Warner, B.G. (2011) Floristic composition and soil characteristics of tropical freshwater forested wetlands of Veracruz on the coastal plain of the Gulf of Mexico. *Forest Ecology and Management* **262**: 1541-1531.

Nizam, MS., Norziana, J., Sahibin, AR. And Latiff, A. (2006) Edaphic relationship among tree species in the National Park at Merapoh, Pahang, Malaysia. *Journal*

Biosains **17**: 37–53.

Oraon PR, Singh L, Jhariya MK. (2018) Forest floor biomass, litterfall and physico-chemical properties of soil along the anthropogenic disturbance regimes in tropics of Chhattisgarh, India. *Journal For Environment Sciences* **34**: 359-375.

Panwar, P., Pal, S., Reza, S.K. and Sharma, B. (2011) Soil Fertility Index, Soil Evaluation Factor, and Microbial Indices under Different Land Uses in Acidic Soil of Humid Subtropical India. *Communication in Soil Science and Plant Analysis* **42**: 2724-2737.

Rao, K. V. (1992) Dynamics of aluminum in base unsaturated soils of Karnataka. Ph. D. Thesis, University of Agriculture Science Bangalore (India).

Salmon, R. C. (1964) Potassium in different fractions of some Rhodesian soils. *Rhodesian Journal of Agriculture Research* **2**: 85-90.

Schroeder, D. (1978) Structure and weathering of potassium containing minerals. *Proc. Congress of International Potash Institute* **11**:43-63.

Sharma, C. M., Ghildiyal, S. K. Gairola, S. and Suyal, S. (2009) Vegetation structure, composition and diversity in relation to the soil characteristics of temperate mixed broad-leaved forest along an altitudinal gradient in Garhwal Himalaya. *Indian Journal of Science and Technology* **2**: 39-45.

Shalini, K., Devenda, H.S., Dhindsa, S.S. and Singh, R.V. (2003) Studies on causes and possible remedies of water and soil Pollution in Sanganer town of pink city. *Indian journal of Environmental Sciences* **1**:47-52.

Singh, D., Chhonkar, P. K and Dwivedi, B.S. (2005) Manual on Soil, Plant and water analysis. Westville Publishing House, New Delhi, 177 pp.

Six, J., Conant, R.T, Paul, E.A. and Paustian, K. (2002) Stabilization mechanisms of soil organic matter: implications for C-saturation of soils. *Plant Soil* **241**: 155-176

Singh, A. H., Singh, R. K. K., Singh, L. N., Singh, N. G., Chongtham,N. and Singh, A. K. K. (2006) Status and forms of sulphur in acidic soils of Manipur. *J. the Indian Society of Soil Science* **54** (3): 351-353.

Singh, A.H., Singh, R.K.K., Singh, N.G., Chongthan, N and Singh, A.K.K. (2006) Status and forms of Sulphur in acidic soils of Manipur. *J. the Indian Society of Soil Science* **54** (3): 351-353.

Stanford S, English L. (1949) Use of flame photometer in rapid soil tests of K. *Canadian Journal of Agronomy* **41:**446 - 447.

Subbaiah, B. V. and Asija, G. L. (1956) A rapid procedure for the estimation of available nitrogen in soils. *Current Science* **25**:259-260.

Tisdale, S.L., Nelson, W.L., Beaton, J. D. and Havlin, J. L. (1995) Soil fertility and fertilizer.5th Ed. Prentice-Hall of India. New Delhi. 684p.

Teixeira, A.P., Assis, M.A., Siqueira, F.R. andCasagrande, J.C. (2008) Tree species composition and environmental relationship in a neotropical swamp forest in southeastern Brazil. *Wetlands Ecology Management* **16**: 451–461.

Van, Breemen, N. And Finzi, A.C. (1998) Plant-soil interactions: ecological aspects and evolutionary implications. Biogeochemistry **42**:1–19

Vesterdal, L., Schmidt, I.K., Callesen, I.C., Nilsson, L.O. And Gundersen, P. (2008) Carbon and nitrogen in forest floor and mineral soil under six common European tree species. *Forest Ecology and Management* **255:**35–48.

Walkley, A. and Black, C. A. (1934) An examination of method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-38.

Whitmore, T.C. (1984) Tropical Rain Forest of the Far East. 2nd ed. London: Oxford University Press.

Yifru and Taye, B. (2011) Effects of land use on Soil Organic Carbon and Nitrogen in Soil of Bale, Southeastern Ethiopia. *Tropical and Subtropical Agroecosystems* **1**:229-235.

Zajicova and Kind Chuman, T. (2019) Effect of land use on soil chemical properties after 190 years of forest to agricultural land conversion. *Soil and Water Research* **14:** 121-131.