Study of soil properties in various agroforestry land use systems in erstwhile Warangal district, Telangana, India

Abstract

A study was conducted to assess the influence of various agroforestry systems on soil physicochemical and chemical parameters in erstwhile Warangal district, Telangana during the year, 2022. Soil samples were collected from 0-20 cm and 20-40 cm depths of different agroforestry land use systems (Eucalyptus, Malabar neem, Sandal wood, Red sanders, Teak, **S**ubabul, Mango + Teak (border plantation), Malabar neem + Sandal wood, Red sanders + Sandalwood plantations) and barren land. The statistical analysis of the data revealed that the soil organic carbon and available nutrients were significantly higher in the surface soil depth (0-20 cm) than the lower depth (20-40cm) irrespective of agroforestry systems. Organic carbon and available nutrients were significantly more under all the agroforestry systems compared to barren land in two depths. There is significant interaction between the land use systems and soil depth. Significantly higher OC (5.12 g kg^{-1}), CEC (18.3 c mol p^{+} kg^{-1}) available N (198 kg ha^{-1}), available P_2O_5 (69 kg ha^{-1}) were recorded at 0-20cm depth in eucalyptus plantation and significantly high K_2O (530 kg ha^{-1}) was recorded in teak plantation. Soil organic carbon significantly and positively correlated with cation exchange capacity (r = 0.839**), available N (r = 0.900 **), available P_2O_5 (r = 0.408**) and available K_2O (r = 0.521**) in all the agroforestry land use systems. Therefore, from this study it was reported that raising tree species in barren lands and also as border plantations improves soil fertility through the addition of leaf litter.

Keywords: agroforestry land use systems, depth, organic carbon, soil available nutrients

1. INTRODUCTION

Trees play a vital role in mitigating the diverse effects of environmental carbon degradation and increasing concentration of carbon dioxide in atmosphere. Most of the carbon enters the ecosystem through the process of photosynthesis in the leaves. After the litter fall, the detritus is decomposed and forms soil organic carbon by microbial process (Gupta and Sharma, 2011). Trees promote sequestration of carbon into soil and plant biomass. Therefore, tree based land use practices could be viable alternatives to store atmospheric carbon dioxide due to their cost effectiveness, high potential of carbon uptake and associated environmental as well as social benefits (Dhruw *et al.*,2009). Deep and extensive root system of trees enables them to absorb substantial quantities of nutrients below rooting zone of crops and transfer them to surface soil. Furthermore, litter fall, root extension and crown expansion facilitate the nutrient cycling and organic matter build-up in the topsoil, leading to improvement of soil properties in the root zone (Mukhopadhyay *et al.*, 2016). Litter production, decomposition and nutrient release pattern from litterfall of trees determine the potential of tree species in improving fertility and productivity of lands (Gleixner *et al.*, 2001; Singh, 2009). The soil organic matter added through decomposing litterfall improves both physical and chemical properties of soil, such as aggregation, water holding capacity and cation exchange capacity of soil (Li *et al.*, 2007; Sartori *et al.*, 2007). The soil organic carbon (SOC) and nutrient content under trees is generally higher than the adjacent open sites (Sartori *et al.*, 2007; Sharma *et al.*, 2015).

The soil organic matter is the most significant ecological element influencing the viability of terrestrial ecosystem since it affects the physical, chemical, and biological properties of the soil, making it a core attribute of soil fertility. Because of the constant inclusion of litter and decomposition operations, the ecological processes in agroforestry systems make the environment more effective in terms of carbon stocking and nutrient cycling. This emphasizes the importance of trees in farmland ecosystems. Keeping this in view, this paper showcases the outcome of the study conducted on influence of tree plantations on soil physicochemical and chemical properties in erstwhile Warangal district.

2. MATERIALS AND METHODS

2.1 Study area

The study was carried out in erstwhile Warangal district which was spread across an area of 12,84,322 ha. It is located between 78° 50’ to 80° 40’East Longitudes and 17° 20’ and 18° 32’ North Latitudes on the southern part of India with an average elevation of 302 meters. The district is in the eastern part of Deccan plateau. The climate is characterized as semiarid to sub humid, subtropical. The annual average temperature stands at 22^{o} Celsius and annual precipitation ranging from 500 to 1200 mm in the region. Monsoon usually lasts from June to September. The district falls under the ‘Isohyperthermic’ soil temperature regime and ‘Ustic’ soil moisture regime (Gahlod *et al.*, 2017). The location Map of the erstwhile Warangal district is depicted in the Fig. 1.

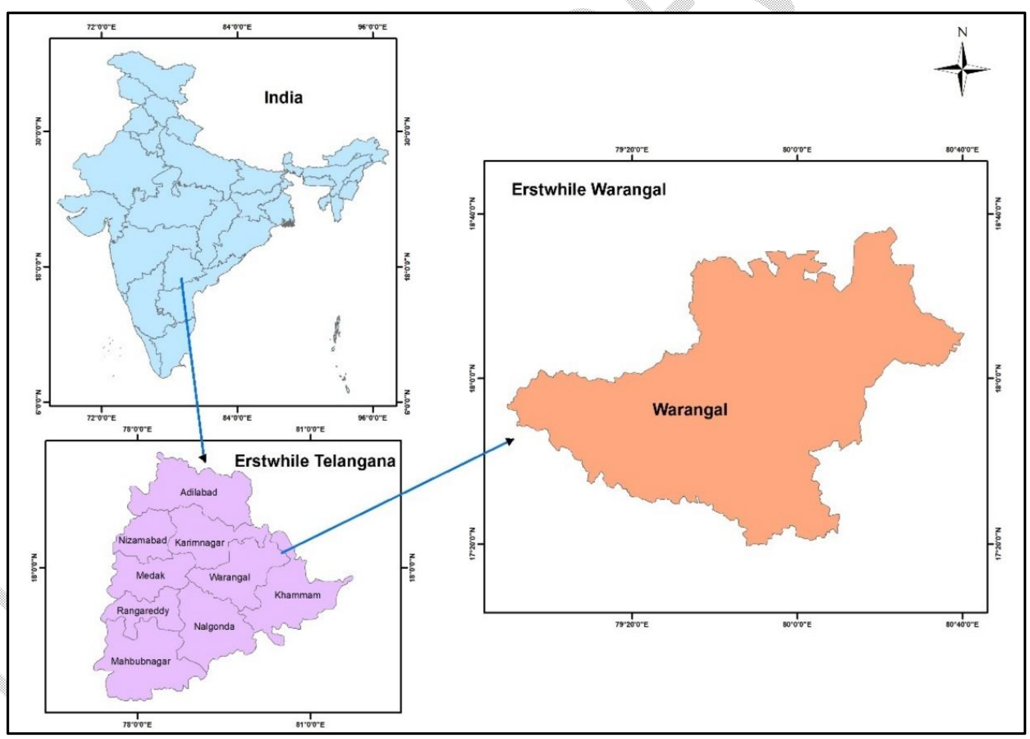

Fig. 1. Location map of erstwhile Warangal district, Telangana

The major soil types found in the district are red chalka (55%), black cotton soil (22%), loamy soil (14%) and sandy loams (9%). Soils in erstwhile Warangal district are moderately shallow to deep soils with the angular blocky and sub angular blocky structure in the surface and sub surface soils, respectively (Rajagopal *et al*., 2013).

Representative villages from different mandals where agroforestry was followed were selected for survey. During survey the agroforestry tree species identified in Warangal district are *Eucalyptus tereticornis* (Eucalyptus), *Melia dubia* (Malabar neem), *Santalum* *album* (Sandalwood) *Pterocarpus santalinus* (Red sanders), *Tectona grandis* (Teak), *Leucaena leucocephala* (**S**ubabul). Majority of the plantations were eucalyptus followed by subabul in erstwhile Warangal district due to the availability of market facility as these plantations pulp wood was taken by ITC, Bhadrachalam for paper making.

2.2 Soil sampling and analysis

Soil samples were collected from different agroforestry land use systems i.e., eucalyptus, malabar neem, red sanders, sandal wood, subabul, teak, mango+ teak, malabar neem + sandal wood, red sanders + sandal wood plantations. Soil samples were taken with the help of an auger from 0-20 and 20-40 cm soil depths. Soil samples were air dried and ground. Thereafter, these samples were passed through a 2 mm sieve and 0.5mm sieve for determination of various soil properties.

Samples collected from various tree species across erstwhile Warangal district were analysed for texture, pH, EC, organic carbon, cation exchange capacity, available N, available P_2O_5, available K_2O. Soil texture was determined through bouyoucos hydrometer method given by Piper (1966). The pH and EC of the soil were determined with distilled water suspension (1:2.5, soil: water) by glass electrode method (Jackson, 1973). Organic carbon was estimated by procedure given by rapid titration method (Walkley and Black, 1934). CEC was determined by taking five grams of soil in a centrifuge tube to which 1N sodium acetate (pH 8.2) was added and centrifuged at 8000 rpm for 5 minutes. The supernatant was discarded and the procedure was repeated thrice. The excess sodium was removed by washing with 33ml of iso propyl alcohol and the supernatant was discarded and repeated thrice. The adsorbed sodium was extracted by 1N ammonium acetate (pH 7) and the supernatant was collected and stored in 100ml volumetric flask (Chapman, 1965). The sodium ions present in the extract was determined by flame photometer.

Available nitrogen was determined by Alkaline permanganate method (Subbiah and Asija, 1956). Available phosphorous was determined by Olsen's method with 0.5M sodium bicarbonate as extractant using double beam spectrophotometer at 420 nm (Olsen *et al*. 1954). Potassium was determined by neutral normal ammonium acetate method using flame photometer (Jackson, 1973).

2.3 Statistical analysis

The soil data was statistically analysed by following the methods of two-way analysis of variance (ANOVA) technique at 5 percent level of probability and the soil parameters were tested for correlation through SPSS (ver.20.0).

3. RESULTS AND DISCUSSION

3.1 Physical properties

The mechanical composition of soil samples i.e., sand, silt and clay were analysed. Soil separates like sand varied from 41.5% to 98%, silt 0 to 50% and clay 0 to 39.78%, respectively. The soils from different agroforestry land use systems in erstwhile Warangal district falls under textural classes i.e., Sandy loam, Sandy clay loam, Sandy, Silt loam, Clay loam, Loamy and Loamy sand. These agroforestry plantations were taken up in light textured soils. Similar classes of soil texture were reported by Rajagopal *et al*. (2013) in erstwhile Warangal district.

3.2 Physico chemical and chemical properties

3.2.1 pH: The soil pH of different land use systems at two depths was given in table 1.

The soils of all the land use systems are neutral to slightly alkaline in reaction (pH 6.77 – 8.1) as per USDA classification**.** Among the agroforestry land use systems pH ranges from 6.77 to 7.87 in 0-20cm depth whereas in 20-40 cm it ranged between 7.21 to 8.10 and barren land has pH of 7.19 and 7.55 in depths 0-20cm and 20-40cm, respectively.

The pH among the agroforestry land use systems was in the order malabar neem > teak > malabar neem +sandalwood > subabul > mango +teak > redsanders > redsanders +sandalwood > sandalwood > eucalyptus. The pH under eucalyptus plantation was lower when compared to other plantations because of higher litter addition in these systems which is acidic in nature, after its decomposition due to release of organic acids. These results are in accordance with Maqbool *et al.* (2017). Pessaraki and Szabolcs (2019) also reported that the organic matter addition reduces the soil pH.

Table.1 The soil pH under different land use systems at two depths

Land use systems (LUS)	**Depth**		**Mean (Land use systems)**
	0-20 cm	**20-40 cm**	
Eucalyptus	6.77	7.20	6.99
Malabar neem	7.87	8.10	7.99
Red sanders	7.22	7.43	7.33
Sandalwood	7.06	7.21	7.14
Subabul	7.40	7.57	7.48
Teak	7.54	7.85	7.69
Mango+ Teak	7.28	7.48	7.38
Malabar neem+ Sandalwood	7.62	7.72	7.67
Red sanders+ Sandalwood	7.07	7.52	7.29
Barren land	7.19	7.55	7.37
Mean(depth)	7.30	7.56	
Interaction	**S.Em+**	**C.D@5%**	
LUS	0.04	0.12	
Depth	0.02	0.05	
LUS x Depth	0.06	0.17	

3.2.2 Electrical Conductivity (dS m^{-1}): The soil electrical conductivity of different land use systems at two depths was given in table 2.

The soil electrical conductivity of different land use systems ranges from 0.18 - 0.37. Normal for all the vegetation as per USDA classification. The EC (dS m^{-1}) ranged from 0.19 to 0.44 in 0-20cm depth and it ranged between 0.18 to 0.36 in 20-40 cm, respectively. Among the agroforestry land use systems the EC (dS m^{-1}) is in the following order malabar neem +sandalwood > teak = mango+ teak > redsanders + sandalwood > subabul = eucalyptus >sandalwood > redsanders. Lowest E.C found in red sanders (0.18 dS m^{-1}) and sandalwood (0.19 dS m^{-1}) at 0-20cm depth. There is an interaction between land use systems and soil depth. Among all the land use systems soil E.C decreased from surface soil (0- 20cm, 0.32 dSm^{-1}) to subsurface soil layers (20-40cm, 0.27 dS m^{-1}), it could be due to uptake of bases by tree biomass, acidic nature of leaf litter after its decomposition and also leaching of bases to lower soil layers. These results are in conformity with Tufa *et al*. (2019) and Geetha *et al*. (2021).

Table 2. The soil electrical conductivity of different land use systems at two depths

Land use systems (LUS)	Depth		Mean (Land use systems)
	0-20 cm	**20-40cm**	
Eucalyptus	0.33	0.25	0.29
Malabar neem	0.30	0.29	0.30
Red sanders	0.19	0.18	0.18
Sandalwood	0.19	0.19	0.19
Subabul	0.31	0.29	0.30
Teak	0.41	0.31	0.36
Mango+ Teak	0.44	0.29	0.36
Malabar neem+ Sandalwood	0.38	0.36	0.37
Red sanders +Sandalwood	0.34	0.30	0.32
Barren land	0.27	0.24	0.26
Mean(depth)	0.32	0.27	
Interaction	**S.Em+**	**C.D@5%**	
LUS	0.01	0.03	
Depth	0.00	0.01	
LUS x Depth	0.01	0.04	

3.2.3 Cation exchange capacity: The CEC (c mol (p^+) per kg) in soils of different land use systems at two depths was given in table 3.

Significantly higher soil cation exchange capacity recorded in Eucalyptus land use system (18.3 cmol (p^+) kg^{-1}) and the lower soil cation exchange capacity was found in barren land (5.5 cmol (p^+) kg^{-1}). Among all the land use systems soil cation exchange capacity significantly decreased from surface soil (0-20 cm –15.2 cmol (p^+) kg^{-1}) to subsurface layer (20-40 cm –13.0 cmol (p^+) kg^{-1}) due to the decrease in organic matter. The cation exchange capacity among all the agroforestry land use sysrems is in the order of eucalyptus > teak > malabar neem > sandalwood > redsanders > mango +teak > malabarneem+ sandalwood > redsanders +sandalwood > subabul compared to barren land with 5.5 c mol (p^+) per kg. Soil organic carbon significantly and positively correlated with cation exchange capacity (r = 0. 839**), due to this reason the CEC recorded high in land use systems where the organic carbon content was high (Geetha *et al.*,2021).

There is interaction between the land use systems and soil depth. Higher soil cation exchange capacity was found in eucalyptus land use system at 0-20cm depth (19.5 cmol (p^+) kg^{-1}) where the organic carbon content was high. The amount and types of clay particles also act as determinant factor on cation exchange capacity of soil under different land use systems. Soil organic matter is the store house of charges, so more CEC was observed on the surface layers as compared to sub-surface soil layers due to decrease in organic matter (Geetha *et al.*,2021). Organic matter imparts exchange capacity through oxalic, carboxylic and other organic acids and ligands (Kassa *et al.*, 2017). Variation in CEC is due to the variations in the rate of humification of organic matter added through the litter fall of different species (Sharma and Sharma, 2004).

Table. 3 The CEC (c mol (p^+) per kg) in soils of different land use systems at two depths

Land use systems (LUS)	Depth		Mean (Land use systems)
	0-20cm	20-40cm	
Eucalyptus	19.5	17.0	18.3
Malabarneem	17.6	14.6	16.1
Redsanders	16.6	13.1	14.8
Sandalwood	17.0	15.0	16.0
Subabul	13.1	11.6	12.4
Teak	18.6	17.0	17.8
Mango+Teak	15.0	12.5	13.8
Malabarneem+Sandalwood	14.2	12.8	13.5
Redsanders+Sandalwood	14.4	12.0	13.2
Barren land	6.0	4.9	5.5
Mean(depth)	15.2	13.0	
Interaction	**S.Em+**	**C.D@5%**	
LUS	0.18	0.52	
Depth	0.08	0.23	
LUS x Depth	0.26	0.74	

3.2.4. Organic carbon: The organic carbon (g kg^{-1}) in soils of different land use systems at two depths was given in table 4.

The results revealed that soil organic carbon contents were significantly affected by different agroforestry systems. There is interaction between the land use systems and soil depth. Significantly higher soil organic carbon recorded in eucalyptus land use systems (6.2 g kg^{-1}) at 0-20 cm depth which was on par with the land use systems of teak (6.1g kg^{-1}), subabul (6.1g kg^{-1}), redsanders (6.0g kg^{-1}) at surface depth and different from all other land use systems where more residue was added through leaf litter (Mengistu *et al.,* 2020). Significantly lower soil organic carbon recorded in barren land in both the depths 0-20 cm (1.4 g kg^{-1}) and 20-40 cm (0.9 g kg^{-1}) due to lower residue accumulation. Greater amount of ether soluble extractives like fat and waxes, alcohol soluble extractives like resin, water soluble extractives (like free sugars) in the eucalyptus residues may contribute higher quantity of organic C (Pandey *et al*., 2000). Thus, huge amount of residues (leaves, branches, bark and especially roots) produced by the Eucalyptus spp. plantation attributes to higher contents of organic matter. This output is in conformity to Leite *et al*. (2010). Variations in organic carbon content in soils under various tree species is attributed to the age of plantation and amount of litter fall, their biochemical composition and rate of their decomposition. These results are in conformity with Bhavya *et al*. (2018).

Among all the land use systems soil organic carbon significantly decreased from surface soil (0- 20 cm – 4.96 g kg^{-1}) to subsurface soil layer (20-40 cm – 2.96 g kg^{-1}). The higher build-up of organic carbon on surface layers of soils attributed to the regular accumulation of litterfall from tree species on soil surface (Geetha *et al*., 2021).

Table 4. The organic carbon (g kg^{-1}) in soils of different land use systems at two depths.

Land use systems (LUS)	**Depth**		**Mean (Land use systems)**
	0-20 cm	**20-40cm**	
Eucalyptus	6.2	4.1	5.12
Malabar neem	5.0	3.1	4.05
Red sanders	6.0	3.9	4.95
Sandalwood	4.7	2.9	3.80
Subabul	6.1	4.0	5.05
Teak	6.1	3.4	4.75
Mango +Teak	5.1	2.8	3.95
Malabarneem+Sandalwood	5.0	2.6	3.83
Redsanders+Sandalwood	4.0	1.7	2.85
Barren land	1.4	0.9	1.17
Mean(depth)	4.96	2.96	
Interaction	**S.Em+**	**C.D@5%**	
LUS	0.08	0.22	
Depth	0.03	0.10	
LUS x Depth	0.11	0.31	

3.2.5. Available N: The available N (kg ha^{-1}) in soils of different land use systems at two depths was given in table 5.

Significantly higher soil available N was found in eucalyptus land use system (198 kg ha^{-1}) which was on par with subabul (194 kg ha^{-1}), teak (191 kg ha^{-1}) and different from all other land use systems and significantly low available N was noticed in barren land (119 kg ha^{-1}). Among all the land use systems soil available N significantly decreased from surface soil (0- 20 cm – 184 kg ha^{-1}) to subsurface soil layers (20-40 cm – 157 kg ha^{-1}). There is an interaction between agroforestry systems and depth. The available N content in lower subsurface soil layers (20-40 cm) was higher (183 kg ha^{-1}) in agroforestry land use systems, when compared to barren land (105 kg ha^{-1}). Similar results were also confirmed by Singh and Singh (2017).

Among the land use systems available N was in the order eucalyptus > subabul > teak > mango+ teak > redsanders > malabar neem > malabar neem + sandalwood = sandal wood > red sanders + sandalwood > barren land. High amount of leaf fall due to its deciduous nature promoted higher available N (213 kg ha^{-1}) in surface soil of eucalyptus plantation, which is almost on par with subabul (209 kg ha^{-1}) whose higher N availability may be attributed to its leguminous nature as it possess higher N concentration in leaf litter. Similar results of high available N in subabul were noticed by Singh and Singh (2017). Lower available N content was noticed in redsanders + sandalwood (140 kg ha^{-1}) rendering that the tree species are in younger age utilising the applied organic manure and soil reserved nitrogen. The differences in available N content under different tree species might be due to variation in total litter production, nutrient concentration of litter and varying rates of mineralization in these species (Sharma and Sharma, 2004).

Table 5. The available N (kg ha^{-1}) in soils of different land use systems at two depths.

Land use systems (LUS)	Depth		Mean (Land use systems)
	0-20 cm	20-40cm	
Eucalyptus	213	183	198
Malabarneem	179	158	169
Redsanders	205	159	182
Sandalwood	182	152	167
Subabul	209	182	194
Teak	206	172	191
Mango+Teak	199	179	189
Malabarneem+Sandalwood	176	158	167
Redsanders+Sandalwood	140	119	130
Barren land	132	105	119
Mean(depth)	184	157	
Interaction	**S.Em+**	**C.D@5%**	
LUS	2.92	8.38	
Depth	1.30	3.75	
LUS x Depth	4.12	11.85	

3.2.6. Available P_2O_5: The available P_2O_5 (kg ha^{-1}) in soils of different land use systems at two depths was given in table 6.

Significantly high available P_2O_5 was recorded in eucalyptus land use system (69.1kg ha^{-1}) which was on par with teak land use system (63.5 kg ha^{-1}) and different from all other land use systems and significantly low available P_2O_5 was observed in barren land (28.3 kg ha^{-1}). Across the land use systems available P_2O_5 significantly decreased from 58.4 kg ha^{-1} (0-20 cm depth) to 48.2 kg ha^{-1} (20-40 cm depth).

The higher content of available P under trees may be due to build up of organic P added through litterfall. Organic compounds in soil release organic acids during decomposition of litterfall and enhance P release by reducing metal ions, binding phosphates through chelation as well as by competing for exchange sites, thus increase availability by the formation of organophosphate complexes that are more easily assimilated by plants. There was significant and positive correlation between organic carbon and available P_2O_5 (r=0.408**). Singh and Singh (2017) also reported higher P under trees than open area where the organic matter was high through the addition of leaf litter.

Table 6. The available P_2O_5 (kg ha^{-1}) in soils of different land use systems at two depths.

Land use systems (LUS)	Depth		Mean (Land use systems)
	0-20 cm	20-40cm	
Eucalyptus	71.7	66.4	69.1
Malabarneem	60.6	56.0	58.3
Redsanders	61.3	54.3	57.8
Sandalwood	46.4	42.3	44.3
Subabul	57.2	49.4	53.3
Teak	68.5	58.5	63.5
Mango+Teak	53.3	48.4	50.9
Malabarneem+Sandalwood	54.4	43.6	49.0
Redsanders+Sandalwood	40.2	37.2	38.7
Barren land	30.4	26.2	28.3
Mean (depth)	54.4	48.2	
Interaction	**S.Em+**	**C.D@5%**	
LUS	1.98	5.69	
Depth	0.88	2.54	
LUS x Depth	2.80	8.04	

3.2.7. Available K_2O: The available K_2O (kg ha^{-1}) in soils of different land use systems at two depths was given in table 7.

Significantly higher soil available K_2O was observed in teak land use system (530 kg ha^{-1}) which was different from all other land use systems and significantly lowest amount (178 kg/ha) was recorded in malabar neem + sandalwood land use system followed by barren land (225 kg ha^{-1}). Soil available K_2O significantly decreased from 0 – 20 cm depth (396 kg ha^{-1}) to 20 - 40 cm depth (307 kg ha^{-1}). There is an interaction between land use systems and soil depth.

The increase in available K concentration under tree plantations may be due to release of K from the K-bearing minerals (Basak *et al.* 2016), solubilization of insoluble forms of K present in soil by organic acids released during decomposition of organic matter, most of K lies free in the plant cell and does not become a part of any cell component and easily release on decomposition (Singh and Sharma 2012., Basak *et al.* 2016).

Table 7. The available K2O (kg ha-1) in soils of different land use systems at two depths.

Land use systems (LUS)	Depth		Mean (Land use systems)
	0-20cm	20-40cm	
Eucalyptus	522	314	418
Malabar neem	439	335	387
Red sanders	427	325	376
Sandalwood	325	292	308
Subabul	418	366	392
Teak	604	456	530
Mango +Teak	266	249	258
Malabarneem+Sandalwood	246	110	178
Red sanders+ Sandalwood	431	398	415
Barren land	280	225	253
Mean(depth)	396	307	
Interaction	**S.Em+**	**C.D@5%**	
LUS	4.82	13.9	
Depth	2.16	6.2	
LUS x Depth	6.82	19.6	

Soil organic carbon significantly and positively correlated with cation exchange capacity (r = 0. 839**), available N (r = 0. 900**), available P_2O_5 (r = 0.408**) and available K_2O (r = 0. 521**) for all agroforestry systems. Geetha *et al.* (2021) also noticed significant and positive correlation of soil organic carbon with cation exchange capacity, available N, available P, available K in agroforestry land use systems. Among all the land use systems soil available nutrients decreased from 0-20 cm to 20-40 cm soil layers which might be reduction of organic matter content along depth of soil. Similar outcome of higher availability of N, P and K on surface layers than subsurface horizon was reported by Geetha *et al.* (2021). The differences in available nutrient content under different tree species might be due to variation in nutrient concentration of litter, total litter production and varying rates of mineralization in these species (Singh and Sharma ,2012).

CONCLUSION

The study concludes that the physicochemical and chemical parameters were higher under agroforestry land use systems over the barren land due to the accumulation of organic matter in the form of litter. The result of this study indicates that eucalyptus plantation has high soil organic carbon (5.12 g kg^{-1}) than other agroforestry systems due to the regular supply of organic matter in the form leaf fall whose residues is rich in various organic compounds. There is significant and positive correlation between OC and soil available nutrients. This emphasizes the importance of agroforestry land use systems, where tree component improves the soil nutrient status and mitigate the CO_2 concentration in atmosphere through accumulation of carbon in the biomass and soil.

REFERENCES

Basak, N., Datta, A., Biswas, S., Mitran, T. and Mandal, B., 2016. Organic amendment influences soil quality in farmers' field under rice-based cropping systems in Indo-Gangetic plains of India. *Journal of the Indian Society of Soil Science* (64) pp138-147.

Bhavya, V., P., Kumar, A., Kiran, S., K., Alur, A., Shivakumar, K., M and Shivanna, M., 2018. Effect of different cropping system on important soil enzyme activity, organic carbon and microbial activity with different depth. International Journal of Current Microbiology and Applied Sciences. 7: 315-322

Chapman, H., D., 1965. Cation exchange capacity. In: Methods of Soil Analysis. Part II, Black, C.A. (Ed.). Agronomy No. 9. *American Society of Agronomy*, Madison, Wisconsin, USA, 891-901.

Dhruw, S., K., Lalji, S. and Singh, A., K., 2009. Storage and sequestration of carbon by leguminous and non-leguminous trees on red lateritic soil of Chhattisgarh. *Indian Forester*, *135*(4), pp.531-538.

Gahlod, N., S., Kumar, Y.S., Chand, M. and Arya, V., S., 2017. Soil resource inventory for assessing soil quality and land capability using geospatial technology. *Journal of Soil and Water Conservation*, 16(1), pp.1-9.

Geetha, K., Chaitanya, T., Padmaja, G. and Krishna, A., 2021. Effect of different land use systems on soil properties. *The Pharma Innovation Journal*, (*10*) pp.01-06.

Gill, A., S. and Burman, D., 2002. Production management of field crops in agroforestry systems. *Recent advances in Agronomy*, pp.523-542.

Gill, H., S, Abrol, I., P and Samra, J., S., 1987. Nutrient recycling through litter production in young plantations of *Acacia nilotica* and *Eucalyptus tereticornis* in a highly alkaline soil. *Forestry Ecol Manage* 22: 57-69.

Gleixner, G., Czimczik, D., J., Kramer, C., Luhker, B. and Schmidt, M., W., I., 2001. Plant compounds and their turnover and stabilization as soil organic matter. In: Global Biogeochemical Cycles in Climate Systems (eds. E.D. Schuitze, M. Heimann, S. Harrison, E. Holland, J.L. Lloyd, C. Prentice and D. Schimel). Academic Press, San Diego, CA, pp. 2010-2015.

Gupta, M., K. and Sharma, S., D., 2011. Sequestrated carbon: organic carbon pool in the soils under different forest covers and land uses in Garhwal Himalayan region of India. *International Journal of Agriculture and Forestry*, *1*(1), pp.14-20.

Jackson, M., L.,1973. Soil Chemical Analysis. Prentice Hall of India Pvt Ltd., New Delhi.

Kassa, H., Dondeyne, S., Poesen, J., Frankl, A. and Nyssen, J., 2017. Impact of deforestation on soil fertility, soil carbon and nitrogen stocks: the case of Gacheb catchment in the White Nile basin, Ethiopia. *Agriculture, Ecosystems and Environment*, (247) pp 273-282.

Leite, F., P., Silva, I., R., Novais, R., F., Barros, N., F., D. and Neves, J., C., L., 2010. Alterations of soil chemical properties by eucalyptus cultivation in five regions in the Rio Doce Valley. *Revista Brasileira de Ciência do Solo*, (34), pp.821-831.

Li, X., G., Li, F., M., Zhan, Z., Y. and Singh, B., 2007. Soil physical properties and their relations to organic carbon pools as affected by land use in alpine pastureland. *Geoderma*, (139) pp143-155.

Maqbool, M., Rasool, R and Ramzan, S., 2017. Soil physico-chemical properties as impacted by different land use systems in district Ganderbal, Jammu and Kashmir, India. *International Journal of Chemical Studies*. 5(4) pp 832-840.

Mengistu, B., Amayu, F., Bekele, W. and Dibaba, Z., 2020. Effects of Eucalyptus species plantations and crop land on selected soil properties. *Geology, Ecology, and Landscapes*, pp.1-9.

Mukhopadhyay, S., Masto, R., E., Yadav, A., George, J., Ram, L., C. and Shukla, S., P.,2016 Soil quality index for evaluation of reclaimed coal mine spoil. *Science of the Total Environment* (542) pp.540-550.

Olsen, S., R., Cole, C., U., Watanabe, F., S., and Deen, L., A., 1954. Estimation of Available Phosphorus in soil by extracting with Sodium bicarbonate; U.S. Government Printing Office: Washington, DCUSDA Circ. 939.

Pandey, C.B., Singh, A., K., and Sharma, D., K., 2000. Soil properties under *Acacia nilotica* trees in a traditional agroforestry system in central India. *Agroforestry systems,* 2000(49) pp53-61.

Pessarakli, M. and Szabolcs, I., 2019. Soil salinity and sodicity as particular plant/crop stress factors. In *Handbook of Plant and Crop Stress, Fourth Edition* (pp. 3-21). CRC press.

Piper, C.S.1966. *Soil and plant analysis.* Bombay: Hans.

Rajagopal, V., Prasadini, P., P., Pazanivelan, S. and Balakrishnan, N., 2013. Characterisation and classification of soils in Warangal district of Central Telangana zone. *Madras Agricultural Journal*, 100(4-6), pp.432-437.

Saravanan, V., Parthiban, K., T., Kumar, P., Marimuthu., 2013. Wood characterization studies on *Melia dubia* Cav. for pulp and paper industry at different age gradation. *Research Journal of Recent Sciences*, (2) pp.183-188

Sartori, F., Lal, R., Ebinger, M., H. and Eaton, J., A., 2007. Changes in soil carbon and nutrient pools along a chronosequence of poplar plantation in the Columbia Plateau, Oregon, USA. *Agriculture, Ecosystems and Environment*, (122) pp.325-329.

Sharma, J., C. and Sharma, Y., 2004. Nutrient cycling in forest ecosystems–A review. *Agricultural Reviews*, *25*(3), pp.157-172.

Sharma, S., Singh, B. and Sikka, R., 2015. Soil organic carbon and nitrogen pools in a chronosequence of poplar (*Populus deltoides*) plantations in alluvial soils of Punjab, India. *Agroforestry Systems*, (89) pp.1049-1063.

Singh, B., 2009. Return and release of nutrients from poplar litterfall in an agroforestry system under subtropical condition. *Journal of Indian Society of Soil Science*, (57) pp.214-218.

Singh, B., and Sharma, K., N., 2012. Depth wise distribution of soil organic carbon and nutrients under some tree species after seventeen years of plantation. *Journal of the Indian Society of Soil Science*, *60*(3), pp.198-203.

Singh, B., Gill, R., I., S., and Kaur, N., 2007. Litterfall and nutrient return in poplar plantation varying in row directions and spacings. *Indian Journal of Agroforestry*, (9), pp.33-37.

Singh, S., and Singh, B., 2017. Depth wise distribution of available nutrients under plantations of multipurpose tree species. *Indian Journal of Agroforestry*, *19*(2), pp.51-55.

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

Tufa, M., Melese., A., Tena, W., 2019. Effects of land use types on selected soil physical and chemical properties: the case of Kuyu district, Ethiopia. *Eurasian Journal of Soil Science*;8(2):94-109.

Walkley, A. and Black, I., A., 1934. Estimation of organic carbon by chromic acid titration method. *Soil Science* (37), pp 29-38.