Study of soil propertiesin 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 the erstwhile Warangal district, Telangana during the year, 2022. Soil samples were collected from 0-20 cm and 20-40cm depths of different agroforestry land use systems (Eucalyptus, Malabar neem, SandalwoodSandalwood, Red sanders, Teak, **S**ubabul, Mango+Teak (border plantation), Malabarneem+SandalwoodSandalwood,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 in 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 (5.12gkg^{-1}), CEC (18.3 cmol p^{+} kg^{-1}) available N (198 kgha^{-1}), and available P_2O_5 (69 kgha^{-1}) were recorded at 0-20cm depth in eucalyptus plantation and significantly high K_2O (530 kgha^{-1})was recorded in the 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 plantationsimproves 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 the concentration of carbon dioxide in the 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 the sequestration of carbon into soil and plant biomass. Therefore,tree basedtree-based land use practices could be viable alternatives to store storingatmospheric 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 The deepand 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 falllitterfall, root extension and crown expansion facilitate the nutrient cycling and organic matter build-up in the topsoil, leading to the improvement of soil properties in the root zone (Mukhopadhyay *et al.*, 2016). Litter production, decomposition and nutrient release pattern patternsfrom litterfall of trees determine the potential of tree species in improving the 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 the soil (Li *et al.*, 2007; Sartori *et al.*, 2007). The soil organic carbon (SOC) and nutrient content under trees is aregenerally 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~~ ecosystemssince 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 the influence of tree plantations onsoil physicochemical and chemical propertiesinthe 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~~ inthe 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~~sub-humid, subtropical. The annual average temperature stands at 22°Celsius and annual precipitation ~~ranging~~ rangesfrom 500 to1200mm in the region. ~~Monsoon~~ The monsoonusually 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.

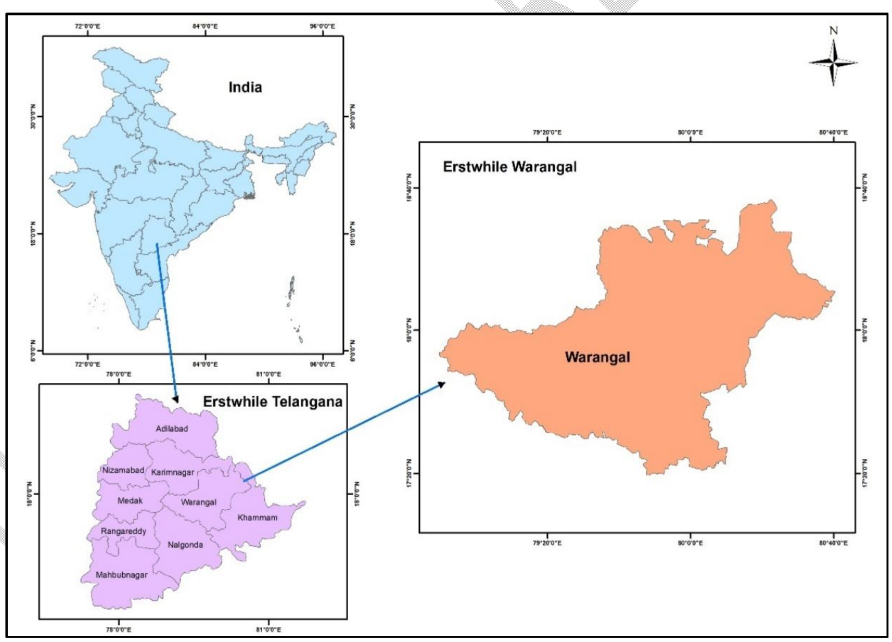

Fig. 1. Location map of erstwhile Warangal district, Telangana

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~~sub-angular blocky ~~structure~~ structuresin the surface and sub surface soils, respectively (Rajagopal *et al.*, 2013).

Representative villages from different mandals where agroforestry was followed were selected for the 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 the erstwhile Warangal district due to the availability of market ~~facility~~ facilitiesas these plantations pulp wood was taken by ITC, Bhadrachalam for paper making.

2.2 Soil sampling and analysis

Soil samples werecollected from different agroforestry land use systems i.e.,eucalyptus, malabarneem, redsanders, ~~sandalwood~~sandalwood, subabul, teak, mango+teak, malabarneem+sandalwood, redsanders+ ~~sandalwood~~sandalwood 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 the erstwhile Warangal district were ~~analysed~~ analyzedfor texture, pH, EC, organic carbon, cation exchange capacity, available N, available P_2O_5, available K_2O.Soil texture was determined through ~~bouyoucos~~ Bouyoucoshydrometer method given by Piper (1966). The pH and EC of the soil were determined with distilled water suspension (1:2.5, soil: water)by the glass electrode method (Jackson, 1973). Organic carbon was estimated by the procedure given byrapid 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~~isopropyl 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~~ weredetermined by a flame photometer.

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

2.3 Statistical analysis

The soil data ~~was~~werestatistically ~~analysed~~analyzedby 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~~Physic 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 the 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 malabarneem > teak >malabarneem+sandalwood >subabul> mango+teak >redsanders>redsanders+sandalwood > sandalwood > eucalyptus.The pH under eucalyptus ~~plantation~~ plantationswas lower when compared to other plantationsbecause of higher litter addition in these systems which is acidic in nature, after its decomposition due to the 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	**20-40cm**	
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 (dSm^{-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 (dSm^{-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 agroforestryland use ~~systems~~systems,the EC (dSm^{-1}) is in the following order malabarneem+sandalwood > teak = mango+teak >redsanders+sandalwood >subabul= eucalyptus >sandalwood >redsanders.Lowest E.C found in red sanders(0.18 dSm^{-1}) and sandalwood (0.19 dSm^{-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	

3.2.3Cation 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 was 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 (0-20cm –15.2 cmol (p^+) kg^{-1}) to subsurface layer (20-40cm –13.0 cmol (p^+) kg^{-1}) due to the decrease in organic matter. The cation exchange capacity among all the agroforestry land use ~~sysrems~~systemsis in the order of eucalyptus> teak >malabarneem >sandalwood >redsanders> mango+teak >malabarneem+sandalwood >redsanders+sandalwood >subabulcompared to barren land with 5.5c 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 inthe 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~~ factorson the cation exchange capacity of soil under different land use systems.Soil organic matter is the ~~store house~~storehouse of charges, so more CEC was observed on the surface layers as compared to sub-surface soil layers due to a 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. 3The 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 (gkg^{-1}) in soilsof 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 0-20cm depth which was on par with the land use systems of teak(6.1gkg^{-1}), subabul(6.1gkg^{-1}), redsanders(6.0gkg^{-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 0-20cm (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~~alcohol-soluble extractives like resin, ~~water soluble~~water-soluble extractives (like free sugars) in the eucalyptus residues may contribute a higher quantity of organic C (Pandey *et al*., 2000). Thus, huge ~~amount~~ amountsof 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~~litterfall, their biochemical composition and the 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- 20cm –4.96g kg^{-1}) to subsurface soil layer(20-40cm –2.96g 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 (gkg^{-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 (kgha^{-1})in soilsof different land use systems at two depths was given in table 5.

Significantly higher soil available N was found in the eucalyptus land use system (198kgha^{-1})which was on par with subabul(194kg ha^{-1}), teak(191kg 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- 20cm –184 kg ha^{-1}) to subsurface soil layers (20-40cm – 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>malabarneem >malabarneem+sandalwood =sandalwood >redsanders+sandalwood>barren land.High amount of leaf~~fall~~falls due to its deciduous nature promoted higher available N (213 kg ha^{-1}) in surface soil ofeucalyptus 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 the eucalyptus land use system (69.1kg ha^{-1}) which was on par with the teak land use system (63.5kgha^{-1}) and different from all other land use systems and significantly lowavailable $P_2O_5$was observedin barren land (28.3kg ha^{-1}). Across the land use systems available P_2O_5significantly 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 (kgha^{-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 soilsof different land use systems at two depths was given in ~~table~~ Table7.

Significantly higher soil available K_2O was observed in the teak land use system (530 kg ha^{-1}) which was different from all other land use systems and the significantly lowest amount (178 kg/ha) was recorded in malabarneem+sandalwoodland 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 decompositionof 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).

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	

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

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 a significant and positive correlation of soil organic carbon with cation exchange capacity, available N, available P, and 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 the depth of soil. ~~Similar~~ A similaroutcome 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 the nutrient concentration of litter, total litter production, and varying rates of mineralization in these species (Singh and Sharma ,2012).

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Environmental factors

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Agroforestry land use systems in tropical zones of Latin America are characterized by the integration of trees, crops, and livestock within the same land area. These systems have gained significant attention due to their potential to enhance soil properties and provide sustainable agricultural practices. In this discussion, we will explore the environmental factors that influence the study of soil properties in various agroforestry land use systems in the tropical zones of Latin America.

Climate:

Climate plays a crucial role in shaping soil properties in agroforestry systems (Zingaretti et al. 2016; Casana and Olivares, 2020). Tropical zones in Latin America often experience high temperatures and high levels of rainfall, which can influence soil erosion, nutrient leaching, and organic matter decomposition (Parra et al. 2012; Olivares et al. 2021; Paredes et al. 2021; Viloria et al. 2023). These climatic factors can vary across different regions within Latin America, leading to variations in soil properties (Rodriguez et al. 2013; Zingaretti and Olivares, 2019). For example, in areas with heavy rainfall, soil erosion may be more pronounced, leading to the loss of topsoil and nutrients (Parra et al. 2017; Cortez et al. 2018; Hernandez et al. 2018). Therefore, understanding the climatic conditions and their impact on soil properties is essential in agroforestry studies.

Vegetation Composition and Diversity:

The type and diversity of vegetation in agroforestry systems significantly influence soil properties. Trees in agroforestry systems contribute to the accumulation of organic matter through litterfall, root exudates, and the incorporation of woody residues into the soil (López-Beltrán et al. 2019). This organic matter enhances soil structure, water retention, nutrient cycling, and microbial activity (Rodriguez et al. 2015; Vega et al. 2022). Additionally, the diversity of plant species in agroforestry systems can enhance soil biodiversity, leading to

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improved nutrient availability and disease suppression (Olivares and Hernández, 2019). The composition and diversity of vegetation, including tree species, crop types, and cover crops, should be considered when studying soil properties in these systems (Hernandez et al. 2020).

Land Management Practices:

The management practices employed in agroforestry systems can greatly influence soil properties. Practices such as the application of organic amendments, mulching, agrochemical use, and tillage intensity can have both positive and negative effects on soil quality (Pittí et al. 2021). Organic amendments, such as compost or manure, can increase soil organic matter content and nutrient availability (Montenegro et al. 2021). Mulching with plant residues or cover crops can protect the soil from erosion, reduce evaporation, and enhance nutrient cycling. Conversely, improper use of agrochemicals and excessive tillage can lead to soil degradation, nutrient imbalances, and loss of soil structure (Orlando et al. 2018; Hernández and Olivares, 2020). Evaluating the impact of different land management practices on soil properties is crucial for sustainable agroforestry systems.

Topography and Landscape Position:

The topography and landscape position of agroforestry systems affect soil properties through their influence on water movement, erosion, and nutrient distribution (Lobo et al. 2023). Sloping landscapes are prone to erosion, which can lead to soil loss and reduced soil fertility. In contrast, flat or gently sloping areas may have better water retention capacity and reduced erosion risks (López and Olivares, 2019). Understanding the topographic features and landscape position is important for assessing soil erosion risks, nutrient distribution patterns, and water availability in agroforestry systems.

Soil Parent Material:

The underlying soil parent material, such as weathered rock or alluvial deposits, influences the initial properties of the soil in agroforestry systems (Araya-Alman et al. 2020). Parent material affects soil texture (Olivares et al. 2022a), nutrient availability (Olivares et al. 2022b), and drainage characteristics. For instance, volcanic soils may have a higher cation exchange capacity and fertility compared to sandy soils. The study of soil properties in agroforestry systems should take into account the influence of soil parent material on soil quality and fertility.

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In conclusion, the study of soil properties in agroforestry land use systems in tropical zones of Latin America is influenced by several environmental factors. Climate, vegetation composition and diversity, land management practices, topography, landscape position, and soil parent material all play significant roles in shaping soil properties in these systems. Understanding the interactions between these factors and their impacts on soil quality iscrucial for future research related to sustainable land management.

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 gkg^{-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 ofagroforestry 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.

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