Range Management and Agroforestry 45 (2) : 306-313, 2024
ISSN 0971-2070 (Print); 2249-5231 (Online)
https://doi.org/10.59515/rma.2024.v45.i2.16

Research article

Effect of different land use types on selected soil characteristics in Erode district, Tamil Nadu

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Received: 19th October, 2023 Accepted: 28th August, 2024

Abstract

An experiment was conducted with thirty cropping systems from six land use types (agriculture, horticulture, silviculture, pastoral, horticulture + agriculture and silviculture + horticulture) to observe the effect of various land use systems on soil properties. The results showed that land use type had a substantial impact on measured soil organic matter (SOM), soil organic carbon (SOC), available nitrogen, phosphorous, potassium, electrical conductivity (EC) and soil reaction (pH). Results showed that agriculture/horticulture based land use systems had considerably higher pH (on an average: 8.30) and EC (0.93 dS m^{-1}) values than did other land use systems. The SOM and SOC in tree-based land use systems were found to be higher than cultivated agri and horti soils. The findings indicated that periodical cultivation of land with agricultural/horticultural crops reduced the soil organic matter, available nitrogen, phosphorous, and potassium while dramatically raising pH and EC. Therefore, for sustainable agricultural productivity, it is necessary to create integrated land management strategies that could aid in restoring soil fertility and limiting soil deterioration.

Keywords: Cropping systems, Land uses, Microbial biomass carbon, Soil fertility, Soil properties

Introduction

Changes in land use alter the landscape and pose serious risks to the environment, including carbon and greenhouse gas emissions (Tian *et al*., 2010), modifications to the energy exchange between the land and atmosphere, and regional climate (Snyder, 2010), land degradation (Drake *et al*., 2004) and biodiversity loss. The amount of biomass, type of vegetation, nutrient management approaches, and other conservation strategies all affect the nutrient status of different land use systems. From a variety of tree species found in natural forests, sacred groves, and coffee agroforestry, a significant amount of biomass is continuously created and supplied to the soil. Use of different tree species generates a continual cycle between above-ground biomass and below-ground root biomass, enhancing the soil's organic carbon pool and fertility. The different land use systems and management or conservation practices play a major role in fixing environmental CO_2 in soil as a carbon.

In India, attempts were made to assess soil quality at a macro level, mostly with the available data. No attempt has been made so far to assess the soil quality at the micro-level. But micro-level study is essential for sustainable forest management, especially in a country like India, where heavy degradation had been caused by anthropogenic activities and different forest management prescriptions of the past warranted in different periods of time to meet the local and national needs (Koppad and Tikhile, 2014). Agroforestry practices have been shown to reduce soil erosion and runoff, maintain soil organic matter, improve soil physical properties, minimize nutrient loss, promote efficient nutrient cycling, sequester carbon and provide numerous ecosystem services (Singh and Gill, 2014). Thus, the evaluation of soil quality under different land use systems is expected to enlighten the agricultural scientific community to tune the management practices. Keeping all these in view, a study on soil quality as influenced by different land use systems in the Erode district of Tamil Nadu was carried out.

Materials and Methods

Description of the study area: The study was conducted in Erode district of Tamil Nadu. Geographically, it extends between 11°.34′ N Latitude and 77º.7′ E Longitude. The altitude ranged from 136 to 177 m above mean sea level. The study area was characterized by a bimodal rainfall distribution with a maximum between October to December (main rainy season) and relatively between June to September. The mean annual rainfall and temperature of the study area ranged from 575 to 833 mm and from 21 to 34°C, respectively. The land use system of the study area was not only purely crop farming (cultivated agri/horti land), but also there were agroforestry systems and grazing lands with sparsely planted trees. Crops such as turmeric, maize, banana, sugarcane, tapioca, tomato, lady finger, brinjal and other vegetables are predominantly grown in this area. Moreover, tree species like coconut, areca nut, mango, guava, jackfruit, etc., are dominantly grown. The agroforestry system of the area was a typical cultural manifestation of the people. Coconut was the main component of the agroforestry system.

Site selection and sampling: The soil sampling was carried out starting from 19 February to 18 March 2020 for a month in the Erode region of Tamil Nadu state. Six types of land use classes were considered: Agri, Horti, Silvi, Pastoral, Horti + Agri and Silvi + Horti. Five cropping systems from each land use system were randomly selected. In this study, thus 30 cropping systems were considered as treatments and the quadrate samples were considered as replications. Sampling points in each cropping system were demarcated in a random manner to have a representative sample collection from the entire field using a core sampler. The collected soil samples from different points in each site were cleared of any organic debris, pooled, homogenized and filled in clean polyethylene bags, labeled and brought to the laboratory for analysis. In the laboratory, the fresh samples from each site were portioned into two halves. One portion is stored in a deep freezer for microbial analysis and another portion is air dried, processed (<2 and 0.5 mm) and stored at 4◦C for each plot for performing other analyses.

Physio-chemical and biological properties: Soil pH and EC were determined using a soil suspension of 1: 2.5 ratio. The samples were oven-dried at 105ºC for 24 hours. SOC was determined by dichromate oxidation (Walkley and Black, 1934). Soil mineralizable or available N was extracted with 2 M KCl for 1-hour and determined by the Kjeldahl method (Waring and Bremner, 1964). Available P was extracted with Olsen's reagent [0.5 M $NaHCO_3$ (pH 8.5)] at a soil-extractant ratio of 1:10, shaken for 30 minutes and quantified by molybdenum–blue colorimetry (Olsen *et al*., 1954). Available K was extracted with neutral normal ammonium acetate (pH 7.0), shaken for 25 minutes and measured by flame photometry (Stanford and English, 1949). The fumigation–extraction method (Vance *et al*., 1987) was adopted to determine soil microbial biomass carbon (MBC). Collected soil samples were enumerated for total culturable aerobic bacteria (TCB), fungi (TCF), and Actinobacteria (ACT) in soil extract agar medium, potato dextrose agar medium and Kenknight's agar medium, respectively, following dilution plating viable count method (Weaver *et al*., 1994).

Statistical analysis: Statistical analyses for the observed data were carried out using IBM SPSS Statistics 25 for Windows (IBM, Inc., Armonk, NY, USA) and results were expressed as mean values with standard error (SE) of two replicated analyses. A completely randomized design was adopted. The significant differences between means were identified using Fisher's least significant differences (LSD) at p = 0.05. To obtain a synergistic relationship among the observed soil indicators, the Pearson Correlation Coefficient was established.

Results and Discussion

Soil reaction pH: The soil pH was not significantly affected by land use types (Table 1) and it ranged from 7.24 in *Psidium guajava* + *Solanum melongena* cropping system to 8.45 in *Zea mays*. The overall mean value of soil pH level distribution in different land-use systems was observed in the order of Agri>Horti>Pastoral>Silvi >Horti+Agri>Silvi+Horti. In general, the soil pH of the study areas was neutral to slightly alkaline in nature. This might be due to a significant increase in microbial oxidation brought on by the addition of organic matter, which resulted in higher organic acid production and better buffering capacity. This was in accordance with the findings of Sharma *et al*. (2015). The constant removal of basic cations by crops, accelerated leaching of basic cations after crop harvest and washing away of exchangeable bases by soil erosion were likely the causes of higher acidity (lower pH) in cultivated land compared to tree-based land use systems. These findings were in line with the findings of Gebrekidan and Negassa (2006), who claimed that soil pH was significantly impacted by land use and management techniques.

Electrical conductivity (EC): In all land use systems, the mean electrical conductivity was below the safe threshold of 1 dS m^{-1} for producing any crop in the research area, with Horti+Agri having the lowest mean value (Table 1). The high level of EC in cropland was probably due to intensive tillage and land management practices, cropping system and nature, salt accumulation from commercial fertilizers, chemical contaminations

Table 1. Soil chemical properties and fertility under different land use systems

Land use system	Crop	pH	Electrical conductivity (dSm^{-1})	Organic carbon (%)
Agri	*Sorghum bicolor*	7.91 ± 0.83	1.20 ± 0.02	0.39 ± 0.01
	Vigna unguiculata	8.08 ± 0.72	0.92 ± 0.05	0.46 ± 0.03
	Eleusine coracana	8.34 ± 0.97	0.71 ± 0.09	0.47 ± 0.06
	Zea mays	8.45 ± 0.59	0.84 ± 0.06	0.48 ± 0.04
	Gossypium herbaceum	8.70 ± 0.63	0.97 ± 0.09	0.57 ± 0.05
Horti	*Curcuma longa*	8.09 ± 0.68	0.29 ± 0.03	0.52 ± 0.06
	Cyamopsis tetragonoloba	8.21 ± 0.94	0.37 ± 0.02	0.53 ± 0.03
	Momordica charantia	7.97 ± 0.58	0.46 ± 0.03	0.59 ± 0.04
	Murraya koenigii	8.17 ± 0.74	0.86 ± 0.06	0.94 ± 0.07
	Abelmoschus esculentus	8.30 ± 0.84	0.63 ± 0.05	1.01 ± 0.08
Horti+ Agri	*Curcuma longa* + *Vigna radiata*	8.04 ± 0.70	0.33 ± 0.01	0.96 ± 0.03
	Curcuma longa + *Vigna aconitifolia*	7.37 ± 0.62	0.34 ± 0.04	1.02 ± 0.13
	Curcuma longa + *Sesbania bispinosa*	7.45 ± 0.10	0.34 ± 0.04	1.13 ± 0.02
	Cyamopsis tetragonoloba + *Gliricidia sepium*	7.68 ± 0.43	0.42 ± 0.04	1.14 ± 0.06
	Curcuma longa + *Crotalaria juncea*	7.84 ± 1.04	0.26 ± 0.03	1.21 ± 0.16
Pastoral	*Pennisetum glaucum*	7.92 ± 0.61	0.58 ± 0.04	0.48 ± 0.04
	Sorghum bicolor (L.) Moench	7.97 ± 0.70	0.45 ± 0.03	0.61 ± 0.05
	Zea mays L.	8.14 ± 0.89	0.72 ± 0.06	0.67 ± 0.07
	Pennisetum purpureum x Pennisetum glaucum	8.01 ± 0.48	0.58 ± 0.07	0.61 ± 0.04
	Stylosanthes guianensis	7.95 ± 0.58	0.79 ± 0.06	0.63 ± 0.05
Silvi	*Cocos nucifera*	7.74 ± 0.57	0.49 ± 0.04	1.16 ± 0.09
	Leucaena leucocephala	7.86 ± 0.65	0.51 ± 0.05	1.26 ± 0.10
	Sesbania grandiflora	7.98 ± 0.29	0.51 ± 0.05	0.68 ± 0.02
	Psidium guajava	8.06 ± 1.00	0.61 ± 0.05	0.99 ± 0.12
	Areca catechu	8.22 ± 0.94	0.79 ± 0.01	1.04 ± 0.12
Silvi+ Horti	*Cocos nucifera* + *Manihot esculenta*	7.32 ± 0.70	0.32 ± 0.02	1.58 ± 0.15
	Psidium guajava + *Solanum melongena*	7.24 ± 0.84	0.49 ± 0.08	0.96 ± 0.06
	Phyllanthus emblica + *Abelmoschus esculentus*	7.69 ± 0.53	0.58 ± 0.05	0.88 ± 0.04
	Areca catechu + *Manihot esculenta*	7.38 ± 0.57	0.29 ± 0.04	1.28 ± 0.09
	Cocos nucifera + *Curcuma longa*	7.31 ± 0.75	0.30 ± 0.02	1.63 ± 0.15

Data: Mean values of two replicates with ± standard error

(from herbicide, insecticide, and fungicide use by farmers), erosion, runoff, animal manures and compost. Similar studies were reported earlier where higher values of EC were observed in cropland soils than in other land-use systems (Dhaliwal and Singh, 2003; Gol, 2009; Kaur and Toor, 2012).

The higher accumulation of organic matter (litter deposition), which decomposed and released higher exchangeable cations (K, Ca, Mg) to the soils, likely contributed to the lower level of EC under natural forest. This reduced the salinity level and decreased the values of electric conductivity in the soils. This result was in consistent with reports from Michelsen *et al.* (1996) and Gol (2009), where natural forests had lower mean electrical conductivity values than other types of land use.

Organic carbon: The SOC concentration showed a significant difference with land use types and it was evident from the data that Horti+Agri land use system rated high category, while cultivated agricultural land had a low rating, and remaining shared medium and high category (Table 1). Among the six land-use systems, the amount of SOC could be rated as Silvi+Horti > Horti+Agri > Silvi > Horti > Pastoral > Agri. The overall mean SOC concentration was higher under Silvi+Horti (1.27 ± 0.42) and lower under agricultural land (0.47 ± 0.09) compared with other land uses. Organic matter also showed a similar trend. Higher OC levels in Horti+Agri land use system could be attributed to higher biomass production and a slower decomposition rate. The difference could be explained by losses of organic matter from soil, lower organic matter being added to the soil through litter inputs and fractions of litter types, and ongoing cultivation that exacerbates organic matter oxidation, which resulted in the loss of carbon from the soil in the form of CO_2. The increased SOC under trees might be attributed to fine root production and turnover, which enriched the soil layer organically (Kaushal *et al*., 2016). Cultivation also exposes the available organic matter to moisture (Reicosky and Forcella, 1998), aeration, and other decomposing agents, facilitating the fast degradation and mineralization (Wild, 2003) of the available organic matter, thereby reducing the soil carbon. These findings were consistent with those of others (Eyayu *et al*., 2009; Selassie *et al*., 2015), who found that cultivated lands had the lowest OM and forest lands had the highest.

Available N: From the study, it was found that the available nitrogen in the six cropping systems was low to medium and the highest nitrogen content was associated with *Cocos nucifera* + *Manihot esculenta* (329 kg ha^{-1}) (Table 2). The lower available N values were observed in the cultivated lands (agri and horti) system, which might be due to continuous cultivation, soil erosion, plant uptake, and volatilization of N resulting from increased oxidation of various nitrogenous compounds. Similarly, low carbon input was added due to the subsistence agricultural production system, which was unable to compensate for the losses of nitrogen by organic matter mineralization, leaching and denitrification.

On the other hand, the relatively high level of available nitrogen found in other plantation crops might be due to the high accumulation of OM, which moderates soil temperature and thereby decreases nitrogen loss by volatilization. Furthermore, it was attributed to long-term accumulation of above and below-ground organic matter inputs from litter fall, root turnover mineralization by actions of soil microbes and N fixation by symbiotics in leguminous plant species diversity in natural forests and other soil microorganisms. This argument was supported by the strong, significant positive correlation (r = 0.744) between nitrogen and organic carbon. Similar studies also reported higher total nitrogen content in natural forests than in other land-use systems in different areas (Lemma *et al*., 2006; Sebhatleab, 2014).

Available P: The available phosphorus content throughout the land use systems was moderate to high (Table 2). The average availability of phosphorous in various land use systems was in the order of Silvi+Horti > Horti+Agri > Silvi > Agri > Horti > Pastoral. This could be attributed to a combination of low nutrient requirements by natural timber plants as compared with different exotic trees species in plantation forests and improved release or mineralization of phosphorus nutrients to soils by the diversity of plant species of different heterogeneity during the decomposition of organic matter. This argument was supported by positive, simple linear correlation relations analyzed between the available phosphorus and the organic carbon (r = 0.801). This result was consistent with the findings of Michelsen *et al*. (1996), Nsabimana *et al*. (2008) and Sebhatleab (2014), who observed a higher concentration of available phosphorus in the natural forest than in other land use systems.

Available K: The exchangeable potassium content in soils of all cropping systems was in the category of medium to high and significantly higher in the agroforestry-based system than in the agricultural lands (Table 2). Among these systems, sorghum (189 kg ha^{-1}) had the lowest mean exchangeable potassium, whereas the highest was observed for *Cocos nucifera* + *Curcuma longa*, followed by *Areca catechu* + *Manihot esculenta* (483 kg ha^{-1}), *Cocos nucifera* + *Manihot esculenta* plantation (444 kg ha^{-1}). The increase in available potassium in the agroforestry system might be due to the incorporation of leaf litter into the soil and it might be ascribed to the reduction of potassium fixation and release of potassium due to the interaction of organic matter with clays, besides the direct potassium addition to the soil.

Microbial biomass carbon: Land-use types significantly influenced soil microbial biomass carbon (MBC) in all the cropping systems (Table 3). Mean MBC varied from 118 ± 6.60 to 502 ± 23.6 μg g^{-1} across the cropping systems. The study locations' varying vegetation types and levels of organic matter ultimately had an impact on the soil's microbial activity. Agroforestry-based land-use systems had the greatest MBC levels because trees produced more litter and had deeper root systems than other agricultural land-use systems. Numerous studies in different ecosystems showed a similar pattern (Soleimani *et al*., 2019; Lepcha and Devi, 2020). A significant positive correlation between soil organic matter and soil microbial biomass (r = 801**) in our study supported findings that soil MBC was heavily influenced by soil organic matter in different ecosystems (Chen *et al*., 2006). Many researchers agreed with this conclusion (Padalia *et al*., 2018: Lepcha and Devi, 2020).

Table 2. Soil available nutrients under different land use systems

Land use system	Crop	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Agri	*Sorghum bicolor*	157 ± 12.2	17.4 ± 1.03	189 ± 13.2
	Vigna unguiculata	201 ± 11.3	17.9 ± 1.00	285 ± 13.0
	Eleusine coracana	208 ± 17.6	23.4 ± 3.11	300 ± 17.7
	Zea mays	216 ± 16.5	24.3 ± 1.86	321 ± 23.4
	Gossypium herbaceum	234 ± 20.6	24.6 ± 2.16	368 ± 22.5
Horti	*Curcuma longa*	203 ± 22.2	18.6 ± 2.04	347 ± 20.7
	Cyamopsis tetragonoloba	217 ± 13.5	19.4 ± 1.21	239 ± 8.34
	Momordica charantia	221 ± 16.2	21.3 ± 1.56	245 ± 17.1
	Murraya koenigii	256 ± 19.0	21.5 ± 1.59	378 ± 10.6
	Abelmoschus esculentus	264 ± 21.9	23.1 ± 1.91	384 ± 28.4
Horti+ Agri	*Curcuma longa* + *Vigna radiata*	234 ± 8.40	24.6 ± 0.88	403 ± 13.9
	Curcuma longa + *Vigna aconitifolia*	251 ± 18.2	37.8 ± 4.71	412 ± 25.8
	Curcuma longa + *Sesbania bispinosa*	255 ± 16.0	35.0 ± 1.99	428 ± 17.7
	Cyamopsis tetragonoloba + *Gliricidia sepium*	256 ± 24.6	32.4 ± 3.11	375 ± 11.1
	Curcuma longa + *Crotalaria juncea*	257 ± 19.8	36.4 ± 4.22	386 ± 8.61
Past-oral	*Pennisetum glaucum*	193 ± 13.4	13.0 ± 0.90	366 ± 17.6
	Sorghum bicolor (L.) Moench	234 ± 16.8	14.6 ± 1.05	373 ± 10.2
	Zea mays L.	244 ± 21.9	18.3 ± 1.64	370 ± 8.34
	Pennisetum purpureum x Pennisetum glaucum	248 ± 20.4	19.7 ± 2.41	381 ± 26.7
	Stylosanthes guianensis	249 ± 18.2	20.4 ± 1.49	390 ± 17.7
Silvi	*Cocos nucifera*	221 ± 20.1	37.8 ± 3.44	310 ± 7.90
	Leucaena leucocephala	241 ± 24.3	48.9 ± 4.93	327 ± 21.7
	Sesbania grandiflora	272 ± 16.1	25.0 ± 2.40	357 ± 13.7
	Psidium guajava	281 ± 23.8	26.9 ± 2.28	364 ± 15.8
	Areca catechu	291 ± 14.3	30.4 ± 1.79	395 ± 19.1
Silvi+ Horti	*Cocos nucifera* + *Manihot esculenta*	329 ± 13.9	95.0 ± 5.33	444 ± 9.22
	Psidium guajava + *Solanum melongena*	235 ± 11.2	89.0 ± 10.2	381 ± 27.8
	Phyllanthus emblica + *Abelmoschus esculentus*	246 ± 18.8	48.3 ± 1.40	368 ± 24.6
	Areca catechu + *Manihot esculenta*	248 ± 21.8	65.6 ± 5.77	483 ± 21.9
	Cocos nucifera + *Curcuma longa*	291 ± 16.3	77.0 ± 8.45	484 ± 28.7

Data: Mean values of two replicates with ± standard error

Microbial population: The microbial populations of different cropping systems were recorded (Table 3). Bacterial population in soil significantly differed under different land use systems and ranged between 18.6 to 112 × 10^8 cfu g^{-1} soil. The highest bacterial population was seen under *Cocos nucifera* + *Curcuma longa* system, followed by coconut + tapioca. The observed values of fungal population were highest (31.6 cfu x 10^3 g^{-1} soil) under silvi + horti land use type followed by silvi and horti + agri land use type soils, whereas the lowest value was recorded in cotton cropping system. The total actinobacterial population ranged from 16.1 to 40.7 cfu x 10^5 g^{-1} soil across land-use types. The highest population was observed under *Phyllanthus emblica* + *Abelmoschus esculentus* and, followed by *Cocos nucifera* + *Curcuma longa* field, whereas the lowest was recorded under eucalyptus plantation. This might be due to the higher availability of fresh litter or/and root exudates at the soil surface to select for microbial communities that were able to rapidly utilize these labile carbon substrates. According to Bharadwaj and Omanwar (1992), an increase in the soil's macronutrient content led to an increase in the fungus

Table 3. Soil microbial carbon and population under different land use systems

Land use system	Crop	Microbial biomass carbon (μg g^{-1})	Bacterial population (CFU x 10^{6} g^{-1} soil)	Fungal population (CFU x 10^{3} g^{-1} soil)	Actino bacteria (CFU x 10^{5} g^{-1} soil)
Agri	*Sorghum bicolor*	156 ± 9.20	39.4 ± 2.32	15.6 ± 0.92	10.7 ± 0.63
	Vigna unguiculata	118 ± 6.60	44.3 ± 2.49	18.1 ± 1.02	22.4 ± 1.26
	Eleusine coracana	145 ± 15.3	18.6 ± 2.47	13.6 ± 1.81	11.2 ± 1.49
	Zea mays	243 ± 18.6	32.4 ± 2.48	16.4 ± 1.26	17.9 ± 1.37
	Gossypium herbaceum	221 ± 19.4	34.6 ± 3.04	14.5 ± 1.28	9.00 ± 0.99
Horti	*Curcuma longa*	164 ± 18.0	27.0 ± 2.96	11.0 ± 1.21	21.2 ± 1.87
	Cyamopsis tetragonoloba	178 ± 11.1	49.0 ± 3.05	15.0 ± 0.93	15.0 ± 0.93
	Momordica charantia	203 ± 14.9	50.4 ± 3.69	19.8 ± 1.45	17.4 ± 1.23
	Murraya koenigii	262 ± 19.4	66.8 ± 4.95	12.1 ± 0.90	19.4 ± 1.44
	Abelmoschus esculentus	224 ± 18.6	64.6 ± 2.36	14.8 ± 1.23	19.6 ± 1.62
Horti+Agri	*Curcuma longa + Vigna radiata*	348 ± 12.5	61.4 ± 2.20	20.8 ± 0.75	23.4 ± 0.84
	Curcuma longa + Vigna aconitifolia	417 ± 14.0	73.8 ± 3.21	24.3 ± 3.03	24.8 ± 3.09
	Curcuma longa + Sesbania bispinosa	401 ± 15.7	71.4 ± 4.21	26.7 ± 3.04	31.4 ± 3.48
	Cyamopsis tetragonoloba + Gliricidia sepium	383 ± 16.8	85.3 ± 4.79	32.1 ± 3.08	34.7 ± 3.23
	Curcuma longa + Crotalaria juncea	428 ± 10.6	94.6 ± 2.50	36.8 ± 2.36	34.7 ± 3.02
Pastoral	*Pennisetum glaucum*	306 ± 14.3	39.5 ± 3.02	19.4 ± 1.35	19.4 ± 1.35
	Sorghum bicolor (L.) Moench	314 ± 22.6	44.6 ± 3.92	10.8 ± 0.78	22.6 ± 1.63
	Zea mays L.	384 ± 15.2	61.1 ± 2.17	13.2 ± 1.19	22.8 ± 2.05
	Pennisetum purpureum x Pennisetum glaucum	229 ± 18.0	37.6 ± 2.34	19.3 ± 2.36	21.4 ± 2.62
	Stylosanthes guianensis	245 ± 17.9	43.2 ± 3.16	19.7 ± 1.44	22.6 ± 1.65
Silvi	*Cocos nucifera*	317 ± 20.9	62.3 ± 3.89	21.8 ± 1.99	24.8 ± 2.26
	Leucaena leucocephala	319 ± 22.2	73.4 ± 2.08	33.6 ± 3.39	29.4 ± 2.97
	Sesbania grandiflora	336 ± 12.2	54.6 ± 1.96	36.5 ± 3.50	32.2 ± 3.09
	Psidium guajava	369 ± 11.2	68.4 ± 1.52	22.5 ± 1.90	26.3 ± 2.22
	Areca catechu	374 ± 19.0	68.6 ± 4.05	26.4 ± 1.56	26.8 ± 1.58
Silvi+Horti	*Cocos nucifera +Manihot esculenta*	445 ± 23.7	102 ± 2.77	33.4 ± 1.87	40.2 ± 2.26
	Psidium guajava + Solanum melongena	416 ± 21.9	96.1 ± 3.12	23.8 ± 3.16	36.7 ± 4.87
	Phyllanthus emblica + Abelmoschus esculentus	387 ± 22.0	66.1 ± 3.04	31.1 ± 2.38	49.1 ± 3.76
	Areca catechu + Manihot esculenta	502 ± 23.6	91.3 ± 3.07	30.2 ± 2.66	32.6 ± 2.87
	Cocos nucifera + Curcuma longa	487 ± 20.8	112 ± 2.34	39.6 ± 2.34	44.7 ± 3.91

Data: Mean values of two replicates with ± standard error

population. For the microbial population to have enough energy, carbonaceous materials and substrates, including amino acids, carbohydrates, and organic acids, are crucial and are abundantly available in tree-based systems.

Correlation matrix: The correlation matrix between the soil organic carbon with soil variables of six different land-use systems (Table 4) showed a strong, significant positive relationship with all the parameters ($p < 0.01$) except

Table 4. Pearson correlation coefficient between soil characteristics

	OC	MBC	pH	EC	N	P	K	ACT	TCB	TCF
OC	1									
MBC	0.801**	1								
pH	-0.655**	-0.709**	1							
EC	-0.560**	-0.568**	0.584**	1						
N	0.744**	0.665**	-0.326**	-0.390*	1					
P	0.801**	0.669**	-0.699**	-0.486**	0.581**	1				
K	0.678**	0.772**	-0.471**	-0.487**	0.720**	0.584**	1			
ACT	0.706**	0.809**	-0.612**	-0.497**	0.682**	0.570**	0.704**	1		
TCB	0.667**	0.785**	-0.599**	-0.431*	0.660**	0.553**	0.657**	0.981**	1	
TCF	0.667**	0.782**	-0.611**	-0.406*	0.663**	0.562**	0.628**	0.975**	0.989**	1

*(p <0.05); **(p <0.01)

for EC and soil pH, where it was negatively significant ($p < 0.01$). SOC exhibited a positive significant relation with available N, available P, available K and microbial biomass carbon but showed negative significance with soil pH and EC ($p < 0.01$). This indicated that carbon inputs from this system through underground and leftover above-ground plant residues were sufficient to maintain the soil carbon content of the sites studied.

Conclusion

The results showed that land use type and their associated management practices significantly affected soil properties. The study concludes that integrating land uses with suitable management practices is the most effective way to maintain and restore soil quality and sustain ecosystem functioning. To strengthen the soil health, a systematic integration of in-depth scientific research on various agricultural systems should be taken into consideration. Therefore, it may be advantageous to restore the depleted soil nutrients for long-term agricultural production and environmental functions by improving current land-use practices through the implementation of proper soil management measures, as well as by introducing the controlled expansion of a fast-growing tree species and effective use of crop residues.

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