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Understanding Carbon, Nitrogen Status and Microbial Population of Incubated Soils from Selected Land Use Systems

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ABSTRACT

An incubation experiment of 120 day was conducted during February, 2023 to July, 2023 at Department of Soil Science, Post Graduate Institute, Rahuri, Maharashtra, India to understand the periodical changes in microbial population, soil organic carbon (SOC) and available nitrogen (AN) status of soils collected from seven land use systems (Agriculture, permanent horticulture, pasture, agroforestry, salt affected, dryland horticulture and fallow land). Samples from seven land use systems were collected at three depths (0–15, 15–30, 30–45 cm) and replicated thrice to statistically analyse using factorial complete randomized design (FCRD). The periodical sample analysis for organic carbon content, available nitrogen content and microbial population (bacteria, fungi and actinomycetes) was done at 0, 30, 45, 60, 75, 90 and 120 days after incubation. Under open pot aerobic incubation study only bacterial count showed slight increase at 30 DAI, while fungal, actinomycetes count, soil organic carbon content and available N showed slight decrease till 45 DAI and later gradual decrease till 120 days across three depths under all the land use types. The bacterial, fungal and actinomycetes count dropped by 20–40% over initial value. Whereas, amount of soil organic carbon and available nitrogen dropped by 40–45% after 120 days of incubation period. A significant gradual reduction in soil properties was observed in all the selected land use systems. The study concluded that type of vegetation cover and plant residue added in soil significantly impacts soil health and nutrient retention capacity over the period of time.

KEYWORDS: Soil health, land use system, carbon and nitrogen

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Land use patterns are simply the ways in which people use a piece of land (Biradar et al., 2024). The balance of ecosystems and the natural quality of land have been seriously disturbed by the rapid conversion of agricultural land into non-agricultural land for civil purposes. Only 29% of the planet is made up of land or soil, making it a finite and non-renewable natural resource. The two primary land use categories-forest and agricultural–make up to 65% of all terrestrial ecosystems on Earth. The remaining topography is made up of marshes, deserts, prairies, tundra, savannas, pasture lands, and glaciers, among other land use types.

Environmental land degradation brought on by human activity was a significant worldwide concern in the 20th century and is now a top concern in the 21st (Lal, 2002; Trivedi et al., 2016). Soil health, a key element of ecological sustainability, has deteriorated as a result of land degradation brought on by poor soil management, intensive tillage, soil erosion, atmospheric pollution, desertification, and the removal of organic matter from the land without its replacement by crop cover (Doran and Zeiss, 2000). The soil biological health is the ability of soil to support large and diverse microbial communities, suppress pathogens, and support healthy crop development (Shahane and Shivay, 2022).

According to Bhowmik et al. (2017), healthy soils are in charge of limiting erosion and the loss of soil organic matter while also offering a favourable environment for microorganisms that are essential to the biogeochemical cycling of plant nutrients. The greatest terrestrial carbon store is soil, and the storage of soil organic carbon (SOC) and aggregate stability are significantly influenced by land use (Saha et al., 2011). Eucalyptus sequesters 6–43 Mg C ha^{-1} yr^{-1} under plantations and agroforestry systems (Prajapati et al., 2024). Critical ecosystem functions including soil organic matter and nutrient dynamics are regulated by land management methods that affect soil microbial diversity and other abiotic environmental factors or driving variables (Doran and Zeiss, 2000). Increased rates of soil organic matter mineralization have resulted in poor soil health due to agricultural intensification, as well as the conversion of natural forests and grasslands to cultivated lands (Guo and Gifford, 2002). Conversion of native forests and pristine soils to cultivation is usually accompanied by decline in SOC content and deterioration of soil structure (Bordoloi and Sharma, 2022).

Nitrogen (N) is a vitally important plant nutrient and is the most frequently deficient of all nutrients (Srinivasan et al., 2016). Since contemporary agriculture relies on the development and usage of inorganic nitrogen fertilizers, food production has had a substantial impact on the global N budget (Fowler et al., 2013). The crop does not use up to 50% of the nitrogen that is applied to the soil (Cameron et al., 2013). This implies that nitrogen may wind up in air or aqueous environments where it could present a serious risk following a series of N transformations. As a result, the regional biogeochemical nitrogen cycles and the cycling of carbon (C) and other elements are altered (Galloway et al., 2003). Changes in microbial populations are expected to impact ecological processes as plant litter decomposition, soil N availability, N cycling and N sequestration.

We hypothesize that biological soil attributes could be used as sensitive indicators of soil health due to its potential to differentiate the effect of different land use systems on soil nutrient cycling and ecological functions. The objective of present study was to analyze the periodical changes in microbial population and carbon, nitrogen status of soils collected from various land use systems, under incubation study of 120 days.

2. MATERIALS AND METHODS

2.1. Study area location and soil sampling

The experiment was conducted during February, 2023 to July, 2023 at Department of Soil Science, Post Graduate Institute, Rahuri, Maharashtra, India. The study area of the research is bound between 19° 20' 19.4316" North, 74° 39' 6.1416" East, and 19° 22' 10.7400" North, 74° 38' 50.1396" East that comes under jurisdiction of Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India. The soil samples were collected during the winter season (January, 2023) at the depth of 0–15 cm, 15–30 cm and 30–45 cm at three locations of each land use system. The soil samples (total 63) were collected in separate sterilized samples bags. Each sample bag was labelled properly with land use types, depth, location, collection date. The GPS readings of this locations were also recorded. The samples were then immediately brought to laboratory and some parts of samples were stored in refrigerator at 4°C for microbial analysis. The details of selected land use systems is given in table 1.

2.2. Incubation study details

An aerobic open pot method incubation study of 120 days was conducted with 63 soil samples. Plastic pots having drain wholes at bottom were used for the experiment. Moisture level was maintained at field capacity by watering the calculated quantity of water in pots every 48 hrs. The shade dried soil samples were first saturated with water completely and weighed initially and after 48 hrs. The amount of water equivalent to difference in weight for each pot was used as water required to keep moisture at field capacity. The periodical sample analysis for organic carbon content, available nitrogen content and microbial population (bacteria, fungi and actinomycetes) was done at 0, 30, 45, 60, 75, 90 and 120 days after incubation.

Table 1: Details of selected land use systems and their GPS location

Tr. No.	LUS	Vegetation of last five years	Latitude	Longitude
T_1	Agriculture	Groundnut/wheat/chickpea/veggies	19° 20' 33.1944" N	74° 38' 54.7944" E
T_2	Permanent horticulture	Sapota plantation	19° 20' 35.4948" N	74° 38' 57.588" E
T_3	Pasture	Marwel/kusli/kathur	19° 20' 35.6316" N	74° 39' 8.3952" E
T_4	Agro-forestry	Eucalyptus+pasture	19° 21' 57.3588" N	74° 39' 12.7152" E
T_5	Salt affected	Wheat/soyabean/sugarcane	19° 20' 26.2248" N	74° 38' 51.72" E
T_6	Fallow	NA	19° 20' 40.344" N	74° 38' 31.6356" E
T_7	Dryland horticulture	Ber or Indian jujube (*Ziziphus mauritiana*)	19° 20' 32.6904" N	74° 39' 32.976" E

2.3. Soil analysis procedures

The soil organic carbon content in soil (0.5 mm sieved) was determined by using Walkley and Black wet digestion method as described by Black (1965). The available nitrogen was determined by alkaline permanganate (0.32% $KMnO_4$) method as explained by Bremner (1965). The method basically described by Halvorsun and Zeigler (1993) with little modification by Chhonkar et al. (2007) was used to study a population of bacteria, fungi, Actinomycetes, from treated soils samples. The microbial population studied for all above-mentioned microbial counts is expressed as cfu g^{-1} of soil.

2.4. Colony forming units of microorganisms

The cfu g^{-1} of soil for all microorganisms was taken by using the serial dilution pour plate technique and with the use of their respective media reported in table 2. Triplicate plates (for each sample and microbial group) were incubated at 28+1°C for one week. Considering characteristics of colonies from respective organisms, the population of each microbial group was measured on the colony counter and expressed as the number of colonies forming unit (cfu) g^{-1} of dry soil (cfu g^{-1} soil). The data was statistically analyzed to calculate standard error and cumulative difference in factorial complete randomised design (FCRD) using OPSTAT.

3. RESULTS AND DISCUSSION

The changes in microbial population, soil organic carbon content and available nitrogen status during 120 days of incubation was as follows:

3.1. Bacterial count

The data in respect of impact of land use systems on bacterial count of soils under 120 days open pot aerobic incubation study is graphically presented in figure 1.

In case of bacterial count significantly superior count was

Table 2: Media and their composition used for growing following microorganisms

Nutrient agar medium (Bacteria)			Potato dextrose agar medium (Fungi)		
1.	Beef extract	3 g	1.	Potato (Peeled)	200 g
2.	Sodium chloride	3 g	2.	Dextrose	20 g
3.	Peptone	5 g	3.	Agar	15 g
4.	Agar	20 g	4.	Distilled water	1000 ml
5.	Sucrose	20 g	5.	pH	6.0–6.5
6.	Distilled water	1000 ml			
7.	pH	6.8–7.2			

Kenknight's agar medium (Actinomycetes)		
1.	Glucose/Dextrose	1 g
2.	Monopotassium phosphate	0.1 g
3.	Potassium chloride	0.1 g
4.	Magnesium sulphate	0.1 g
5.	Agar	15 g
6.	Sodium nitrate	0.1 g
7.	Distilled water	1000 ml
8.	pH	7.0–7.2

observed in agroforestry land at all the stages i.e, initial (83.22 cfu×10^6 g^{-1} soil), 30 DAI (82.56 cfu×10^6 g^{-1} soil), 45 DAI (79.89 cfu×10^6 g^{-1} soil), 60 DAI (77.89 cfu×10^6 g^{-1} soil), 75 DAI (74.67 cfu×10^6 g^{-1} soil), 90 DAI (73.56 cfu×10^6 g^{-1} soil) and 120 DAI (69.33 cfu×10^6 g^{-1} soil). A slight increase over initial bacterial population of surface soils was observed at 30 DAI, which could be due to initially available active carbon for microbial utilization.

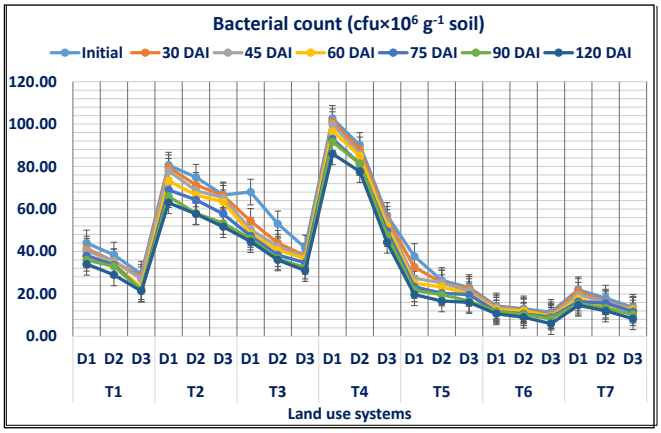

Figure 1: Effect of land use systems on bacterial count under 120 days incubation

Agroforestry system was followed by other land use systems in descending order as, permanent horticulture>pasture> agriculture>salt affected>dryland horticulture>fallow land at all the stages of incubation period. As per the figure 4, overall 25.53% decrease in total bacterial count was reported after 120 days. 25 to 48% decrease was reported in fallow and salt affected land, while lowest per cent decrease i.e, 16 to 24% was reported in agroforestry and permanent horticulture. This might be attributed to high availability of organically stable carbon in plantation land forms, that helped for bacteria to survive for longer time in absence of fresh biomass. Also, bacteria showed lowest per cent decrease than fungus and actinomycetes due to their ability to survive adverse conditions along with its high diversity under natural vegetation. This suggests that, in semi-arid environments, the bacterial population is likely more metabolically active than the fungal population (Latha et al., 2022).

The bacterial count significantly and gradually decreased with increasing depths across all the land use systems and at all the stages of incubation (0–120 days). This was based on the fact that at higher depth the available biomass declined significantly. At all the stages of incubation study, statistically significant interaction effect was seen between LUS and depth.

According to Latha et al. (2022), the population of soil bacteria increased somewhat up to 45 DAI before slowly declining till 90 DAI. The treatment with crop residue experienced the lowest drop, whereas the control group experienced the largest decline. Similarly, Nagar et al. (2016) also showed an increased trend in soil microorganisms as a result of residue incorporation. Plant residue decomposition period affects the percentage of actinobacteria, proteobacteria, acidobacteria, and fungi that belong to the Ascomycota class, as stated by Strickland et al. (2009).

3.2. Fungal count

In case of fungal count significantly superior count was reported in pasture land (T_3) and followed by agroforestry land (T_4) at all the stages i.e, initial (35.22 cfu×10^4 g^{-1} soil), 30 DAI (32.56 cfu×10^4 g^{-1} soil), 45 DAI (30.33 cfu×10^4 g^{-1} soil), 60 DAI (29.11 cfu×10^4 g^{-1} soil), 75 DAI (26.89 cfu×10^4 g^{-1} soil), 90 DAI (25.78 cfu×10^4 g^{-1} soil) and 120 DAI (24.67 cfu×10^4 g^{-1} soil). A gradual decrease in count over the period was observed across all the seven treatments (Figure 2). The salt affected land and fallow land were statistically at par with each other at all the stages with lowest fungal count indicating that soil fungus failed to survive extreme stressed conditions.

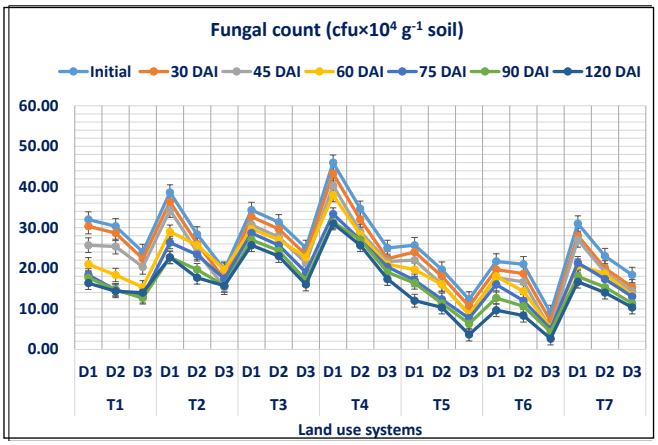

Figure 2: Effect of land use systems on fungal count under 120 days incubation

Almost 40.65% decrease in fungal count was recorded after 120 DAI. 50 to 70% decrease in fungal count was reported in salt affected and fallow land, whereas, only 20 to 30% decrease was reported in agroforestry and pasture land (Figure 4). Funguses are more sensitive to changes in soil pH, nutrients and harsh environments than bacteria, causing higher percent decrease in fungal population. The fungal population even significantly declined with deeper depths from surface (0–15 cm) to subsurface layers (30–45 cm) due to low biomass availability at deeper depths.

A particular category of fungus, known as lignolytic fungi, are specialized complex polymer degraders, while most fungi feed on simple, soluble substances like sugars. Fungi break down the most resistant component in the final stage

of degradation (Ruess and Ferris, 2004). The soils of land use systems such as pasture, agroforestry and permanent horticulture are rich in complex molecular biomolecules such as lignin, terpenes, phenols that help proliferation of higher fungi. The order in which soil influence the total number of fungi was forest>eucalyptus>sorghum. (Vieira and Nahas, 2005). In comparison to other soils, eucalyptus soil displayed an intermediate number of counts, supporting the idea that plant species also influence the size and makeup of microbial communities in addition to soil type. The literatures are available on the relationships of plant species, soil, and microbial populations (Marschner et al., 2001).

Similar to bacterial count, the interaction between land use systems and soil depths was statistically non-significant at all the stages of incubation except at initial stage where significant interaction was reported with CD value of 5.40. Similar line of results were reported by Govaerts et al. (2006) and Noya et al. (2013) inferring the importance vegetative cover and residue addition for improving microbial abundance.

3.3. Actinomycetes count

The findings pertaining to actinomycetes count across seven land use systems and soil depths under incubation study is depicted in figure 4. The actinomycetes count (Figure 3) was significantly superior in agroforestry land (T_4) at all the stages i.e, initial (56.22 cfu×10^6 g^{-1} soil), 30 DAI (59.00 cfu×10^6 g^{-1} soil), 45 DAI (56.33 cfu×10^6 g^{-1} soil), 60 DAI (53.33 cfu×10^6 g^{-1} soil), 75 DAI (51.11 cfu×10^6 g^{-1} soil), 90 DAI (49.89 cfu×10^6 g^{-1} soil) and 120 DAI (32.67 cfu×10^6 g^{-1} soil). This was followed by pasture land (T_3) and sapota based permanent horticulture (T_2) at all the stages. While, the land use systems such as agriculture and dryland horticulture as well as salt affected land and fallow land were statistically at par with each other except at 120 DAI where agriculture and dryland horticulture were non-significant with each other.

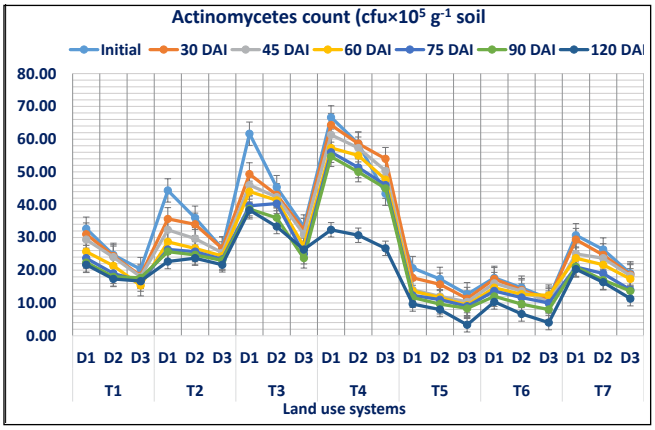

Figure 3: Effect of land use systems on actinomycetes count under 120 days incubation

Similar to bacterial and fungal population, a linear decrease in actinomycetes count was observed along depths, D_1 (0–15 cm), D_2 (15–30 cm) and D_3 (30–45 cm). Over all 39.56% decrease was reported in actinomycetes count after 120 days of incubation. 64 to 74% decrease was observed in fallow and salt affected land. The relatively low decrease was observed in permanent horticulture and agriculture land (Figure 4).

Actinomycetes population grew up to 45 days of incubation

Soil properties		Bacteria	Fungus	Actinomycetes	SOC	AN
Total % Decrease		25.53	40.65	39.56	45.19	40.32
T1	D1	22.73	48.96	33.67	52.58	39.27
Agri	D2	24.35	52.75	29.73	61.04	42.70
	D3	27.27	41.67	18.03	60.47	43.95
T2	D1	21.90	41.38	48.87	29.48	32.20
Prm. Horti	D2	23.11	37.65	34.26	25.93	24.00
	D3	22.50	20.34	18.75	30.17	37.43
T3	D1	34.31	25.24	37.84	38.81	32.22
Pasture	D2	32.08	26.60	26.47	37.17	34.07
	D3	25.60	36.00	21.00	46.30	33.81
T4	D1	16.23	32.61	51.50	33.50	32.43
Agroforest	D2	13.70	25.96	47.73	40.63	32.85
	D3	22.22	30.67	38.46	52.44	38.59
T5	D1	47.79	53.25	53.23	58.82	50.62
Salt affect.	D2	36.71	47.46	53.85	67.12	51.97
	D3	30.43	70.27	73.68	81.58	63.83
T6	D1	25.58	55.38	41.51	53.13	55.65
Fallow	D2	30.77	60.32	54.55	72.09	69.49
	D3	47.06	70.37	64.71	78.95	70.00
T7	D1	33.33	46.24	33.70	35.62	36.36
Dryld Horti	D2	33.33	39.13	37.97	54.87	42.33
	D3	39.02	43.64	40.35	70.49	48.10

Figure 4: Heatmap showing per cent decrease in soil microbial count, organic C and available N after 120 days of incubation across LUS

(DAI) and then declined as the number of days of incubation increased (Latha et al., 2022). Actinomycetes population growth may have resulted from the availability of substrate in the form of simple sugars for nutrition, which then declined as a result of competition from other bacterial species. According to Vieira and Nahas (2005), when casein-starch medium was utilized, the counts of actinomycetes were highest in sorghum soil. The number of actinomycetes was larger in forest soil than in other soils.

Therefore, it's possible that a selection impact contributed to the variance in microbial counts when populations of microorganisms quickly adapted to an agroecosystem that had been altered by various plants and soil types (Atlas and Barna, 1987). Nonetheless, it has been demonstrated by other researchers (Miethling et al., 2000; Pinto and Nahas, 2002; Sanomiya and Nahas, 2003) that distinct plant species affect the distribution of microbial communities in the same soil type.

The interaction effect of land use systems and soil depths was statistically non-significant at initial, 30 DAI and 45 DAI, while it was statistically significant at 60 DAI, 75 DAI, 90 DAI and 120 DAI with CD values of 5.46, 5.28, 3.90 and 3.15, respectively.

3.4. Soil organic carbon

Based on the data given in Table 3, the significantly highest organic carbon content was reported in permanent

horticulture land (T_2) which was at par with agroforestry land (T_4) at initial, 30 DAI, 60 DAI, 75 DAI, 90 DAI and 120 DAI with soil organic carbon content of 0.71%, 0.67%, 0.65%, 0.61%, 0.56% and 0.49%, respectively. While, at 30 DAI and 60 DAI it was at par with pasture land (T_3). At 45 DAI (0.64%) organic carbon content of permanent horticulture was significantly superior over all the treatments. The organic carbon content in remaining land use systems decreased in following order: Pasture>dryland horticulture>agriculture>salt affected land>fallow land.

Highest per cent decrease observed in soil organic carbon content (Figure 4) was in salt affected and fallow land (53 to 82%). It might be due to utilization of carbon by microbes as well as highest loss of carbon as carbon dioxide under open air condition. The lowest per cent decrease was observed in permanent horticulture (25 to 30%), followed by pasture (37 to 47%) and agroforestry land (33 to 53%). These findings suggest that the addition of residues boosted soil biological activity and accumulation of stabilized C in soil. Whereas, total per cent decrease in soil organic carbon content was 45.19% over initial SOC.

The high content of cellulose, hemicellulose, and lignin in

Table 3: Effect of land use systems on soil organic carbon content (%) under incubation study

	0 Days incubation				30 Days after incubation				45 Days after incubation				60 Days after incubation			
T/D	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
T_1	0.49	0.39	0.22	0.36	0.41	0.37	0.20	0.32	0.37	0.31	0.17	0.28	0.38	0.30	0.16	0.28
T_2	0.87	0.68	0.58	0.71	0.79	0.66	0.57	0.67	0.74	0.61	0.56	0.64	0.79	0.65	0.51	0.65
T_3	0.67	0.57	0.54	0.59	0.61	0.54	0.52	0.56	0.58	0.48	0.47	0.51	0.63	0.52	0.50	0.55
T_4	1.02	0.48	0.41	0.64	0.94	0.42	0.35	0.57	0.88	0.38	0.32	0.53	0.94	0.42	0.35	0.57
T_5	0.43	0.37	0.19	0.33	0.32	0.27	0.10	0.23	0.29	0.24	0.08	0.20	0.32	0.27	0.10	0.23
T_6	0.32	0.22	0.19	0.24	0.29	0.18	0.16	0.21	0.26	0.16	0.14	0.19	0.29	0.15	0.12	0.18
T_7	0.73	0.57	0.31	0.53	0.72	0.54	0.25	0.50	0.71	0.49	0.21	0.47	0.64	0.42	0.17	0.41
Mean	0.64	0.46	0.35		0.58	0.42	0.31		0.54	0.38	0.28		0.57	0.39	0.27	
Inter	SEm±		CD (p=0.05)		SEm±		CD (p=0.05)		SEm±		CD (p=0.05)		SEm±		CD (p=0.05)	
T	0.04		0.10		0.03		0.10		0.03		0.10		0.04		0.10	
D	0.02		0.07		0.02		0.07		0.02		0.07		0.02		0.07	
T×D	0.06		0.18		0.06		0.18		0.06		0.17		0.06		0.18	

T_1: Agriculture land; T_2: Permanent horticulture land; T_3: Pasture land; T_4: Agroforestry land; T_5: Salt affected land; T_6: Fallow land; T_7: Dryland horticulture land

	75 Days after Incubation				90 Days after Incubation				120 Days after Incubation			
	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
T_1	0.35	0.27	0.15	0.26	0.30	0.22	0.12	0.21	0.23	0.15	0.09	0.16
T_2	0.75	0.62	0.48	0.61	0.70	0.57	0.43	0.56	0.61	0.50	0.35	0.49
T_3	0.58	0.49	0.45	0.50	0.51	0.42	0.39	0.44	0.41	0.36	0.29	0.35
T_4	0.87	0.38	0.32	0.52	0.79	0.34	0.26	0.46	0.68	0.29	0.20	0.39
T_5	0.29	0.24	0.08	0.20	0.24	0.19	0.07	0.17	0.18	0.12	0.04	0.11
T_6	0.25	0.14	0.11	0.16	0.20	0.10	0.09	0.13	0.15	0.06	0.04	0.08
T_7	0.58	0.37	0.14	0.36	0.52	0.31	0.12	0.31	0.47	0.26	0.09	0.27
Mean	0.52	0.36	0.24		0.46	0.31	0.21		0.39	0.25	0.16	
Inter	SEm±		CD (p=0.05)		SEm±		CD (p=0.05)		SEm±		CD (p=0.05)	
T	0.03		0.10		0.03		0.10		0.03		0.09	
D	0.02		0.06		0.02		0.06		0.02		0.06	
T×D	0.06		0.17		0.06		0.17		0.05		0.15	

T_1: Agriculture land; T_2: Permanent horticulture land; T_3: Pasture land; T_4: Agroforestry land; T_5: Salt affected land; T_6: Fallow land; T_7: Dryland horticulture land

sapota, eucalyptus, pasture and ber might hinder residue decomposition, that accounts for the low CO_2 emissions with high C: N residues (Ferraz-Almeida et al., 2020). High quantities of C in residue require many cycles and additional time for microorganisms to break it down. Furthermore, microbes use the C substrate as a building block for their cells and as a source of energy during the breakdown process (Rahman, 2013). Ferraz-Almeida (2022) found that adding residue to soil during a 50-day incubation study altered the daily C and N levels of soil. The microbial decomposition of organic waste and soil respiration by roots and fauna are the sources of CO_2 emissions (Luo and Zhou, 2006).

The initial week revealed a rapid native carbon mineralization, which thereafter slowed down (Kaur et al., 2023). Several researchers have previously found that the breakdown of organic matter is greatly influenced by the moisture content in addition to the native SOC content (Yin et al., 2019). It could be explained by the reduced microbial activity of aerobic population and respiration at moisture concentrations higher than field capacity (Yadav et al., 1989). Until 45 days at field capacity, organic carbon grew by 33.3% of the initial contents but decreased by 16.3% of the initial values after 45 days. The loss of carbon as CO_2-C over time may be the cause of the decrease in organic carbon content.

3.5. Available nitrogen

The findings regarding variation in available nitrogen content of soils from various land use systems while under 120 days incubation study is mentioned in Table 4. In case of available nitrogen content, significantly highest content was observed in pasture land (T_3) at initial stage (235.2 kg ha^{-1}), 30 DAI (223.4 kg ha^{-1}), 75 DAI (187.8 kg ha^{-1}) and 120 DAI (156.8 kg ha^{-1}), which was at par with (T_2) permanent horticulture (229.3 kg ha^{-1}, 224.4 kg ha^{-1}, 187.1 kg ha^{-1} and 156.1 kg ha^{-1}) and (T_4) eucalyptus-based agroforestry land (226.5 kg ha^{-1}, 178.7 kg ha^{-1}, 148.8 kg ha^{-1}). At 45 DAI (213.6 kg ha^{-1}), 60 DAI (202.8 kg ha^{-1}) and 90 DAI (173.5 kg ha^{-1}) significantly highest available nitrogen was reported in permanent horticulture land which was at par with pasture (212.9 kg ha^{-1}, 202.1 kg ha^{-1}, 172.8 kg ha^{-1}) and agroforestry land (205.2 kg ha^{-1}, 193.0 kg ha^{-1}, 165.2 kg ha^{-1}).

The average per cent decreases in available nitrogen was 40.32% after 120 days (Figure 4). 50 to 70% decrease in available nitrogen was noted in salt affected (T_5) and fallow land (T_6) over initial value. The lowest decrease was observed in permanent horticulture, followed by pasture and agroforestry land. This might be due to utilization of available nitrogen by microbes for their metabolic activities as well as loses of nitrogen in gases form as, nitrites. The available nitrogen declined significantly and rapidly with deeper depths from surface to subsurface layers. A statistically significant interaction effect between land use systems and soil depth was reported for available nitrogen content.

As these soils collected from land use systems were directly kept for incubation without addition of any substrate that

Table 4: Effect of land use systems on available nitrogen content (kg ha^{-1}) under incubation study

T/D	0 Days incubation				30 Days after incubation				45 Days after incubation				60 Days after incubation			
	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
T_1	199.7	186.1	164.1	183.3	184.0	176.7	157.9	172.8	175.6	164.1	146.4	162.0	163.1	153.7	138.0	151.6
T_2	276.0	224.8	187.1	229.3	259.2	234.2	179.8	224.4	248.8	221.6	170.4	213.6	237.3	213.3	157.9	202.8
T_3	249.8	236.3	219.5	235.2	240.4	220.6	209.1	223.4	228.9	211.2	198.6	212.9	216.4	201.8	188.2	202.1
T_4	270.7	216.4	192.3	226.5	250.9	209.1	179.8	213.3	242.5	201.8	171.4	205.2	233.1	188.2	157.9	193.0
T_5	169.3	132.8	98.3	133.5	149.5	120.2	85.7	118.5	139.0	111.9	80.5	110.5	126.5	103.5	70.0	100.0
T_6	129.6	123.4	94.1	115.7	117.1	112.9	86.8	105.6	109.8	94.1	81.5	95.1	95.1	79.5	68.0	80.8
T_7	218.5	197.6	165.2	193.7	205.9	178.8	150.5	178.4	194.4	168.3	142.2	168.3	180.8	157.9	132.8	157.2
Mean	216.2	188.2	160.1		201.0	178.9	149.9		191.3	167.6	141.6		178.9	156.8	130.4	
Inter	SEm±		CD (p=0.05)		SEm±		CD (p=0.05)		SEm±		CD (p=0.05)		SEm±		CD (p=0.05)	
T	4.46		12.77		2.90		8.31		3.19		9.12		3.41		9.76	
D	2.92		8.36		1.90		5.44		2.09		5.97		2.23		6.39	
T×D	7.72		22.12		5.02		14.39		5.52		15.80		5.90		16.91	

T_1: Agriculture land; T_2: Permanent horticulture land; T_3: Pasture land; T_4: Agroforestry land; T_5: Salt affected land; T_6: Fallow land; T_7: Dryland horticulture land

Table 4: Continue...

	75 Days after Incubation				90 Days after Incubation				120 Days after Incubation			
	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean	D_1	D_2	D_3	Mean
T_1	148.4	139.0	122.3	136.6	130.7	124.4	112.9	122.7	121.3	106.6	92.0	106.6
T_2	221.6	195.5	144.3	187.1	204.9	184.0	131.7	173.5	187.1	165.2	116.0	156.1
T_3	201.8	187.1	174.6	187.8	187.1	173.5	157.9	172.8	169.3	155.8	145.3	156.8
T_4	215.3	175.6	145.3	178.8	201.8	161.0	132.8	165.2	182.9	145.3	118.1	148.8
T_5	110.8	87.8	59.6	86.1	98.3	79.5	50.2	76.0	83.6	63.8	35.5	61.0
T_6	80.5	65.9	54.4	66.9	66.9	52.3	40.8	53.3	57.5	37.6	28.2	41.1
T_7	167.3	143.2	118.1	142.9	150.5	130.7	101.4	127.5	139.0	113.9	85.7	112.9
Mean	163.7	142.0	116.9		148.6	129.3	103.9		134.4	112.6	88.7	
Inter	SEm±		CD (p=0.05)		SEm±		CD (p=0.05)		SEm±		CD (p=0.05)	
T	3.61		10.35		4.26		12.21		4.21		12.07	
D	2.37		6.78		2.79		7.99		2.76		7.90	
T×D	6.26		17.93		7.39		21.15		7.30		NS	

T_1: Agriculture land; T_2: Permanent horticulture land; T_3: Pasture land; T_4: Agroforestry land; T_5: Salt affected land; T_6: Fallow land; T_7: Dryland horticulture land

could help microbial activity, the microbes present used whatever available organic material and available nutrients for their survival that resulted into gradual decrease in available nitrogen status over the period. The soils from plantation fields comparatively had higher particulate organic material as compared to cropped and fallow land that resulted into significantly highest nitrogen content in earlier land use systems.

According to Beek and Frissel (1973), first-order kinetics regulate the oxidation of NH_4^+ as well as the mineralization of proteins, sucrose, cellulose, lignin, and live biomass. The immobilization, NH_3 volatilization by diffusion, and NH_4^+ clay fixing may be the cause of the abrupt drop in the available nitrogen status (Frissel and van Veen, 1981). The outcomes coincide with those of Dey et al. (2019), and Preusch et al. (2002). The decline in nitrogen concentration in the soil in our study is likely related to a residue sample of trees that has leaves and shoots, which have a relatively larger nitrogen content. The possibility of N immobilization in residues with a high C:N ratio has also been shown in earlier research (Vargas et al., 2014).

4. CONCLUSION

The average bacterial, fungal, actinomycetes count, SOC and AN content reduced by 25.53%, 40.65%, 39.56%, 45.19% and 40.32%, respectively over the initial content with highest reduction in fallow land, while lowest in agroforestry and pasture. The study further inferred that, type of land use cover and type of plant residue added in soil over the years significantly affects the retention of soil organic carbon and available nitrogen content along with efficacy of microbial activity in absence of fresh residue addition.

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