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Assessing soil characteristics across different land use systems in the northern transect of Bangalore: A comparative study of chemical and biological properties

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Abstract
To study the impact of different land use system management practices on soil chemical and biological properties in the rural regions of the northern transect of Bangalore, a study was conducted during the year 2021 to 2023. Three land use systems such as horticulture, organic farming, and sericulture land use systems were selected from the northern transect of Bangalore. From each land use system, twenty surface samples were collected at a depth of 0-15 cm, and analyzed for various chemical and biological properties. The pH levels recorded from the three land use systems do not show any significant difference. However, a significantly higher level of electrical conductivity was recorded from the horticulture (0.44 dSm^{-1}) land use system. This might be due to the application of inorganic fertilizers in the horticulture land use system. Furthermore, a higher level of available nitrogen, phosphorus, and potassium were recorded from horticulture land use systems (N- 312.35 kg ha^{-1}, P- 31.13 kg ha^{-1}, K- 287.22 kg ha^{-1},) in comparison to sericulture (N- 286.33 kg ha^{-1}, P- 28.96 kg ha^{-1}, K- 242.14 kg ha^{-1}) and organic farming (N- 252.74 kg ha^{-1}, P- 25.38 kg ha^{-1}, K- 252.62 kg ha^{-1},) land use system. Similar trends were observed for micronutrient levels across the three land use systems. A significant difference was recorded in organic carbon content across different land use systems. In terms of biological properties, dehydrogenase activity, urease activity, carbon-nitrogen biomass, and nitrogen fixers were found to be most abundant in organic farming land-use systems. This study underscores the substantial influence of land use systems and their management practices on both the chemical and biological properties of soil in the rural regions of the northern transect of Bangalore. The findings not only contribute to a better understanding of soil health but also emphasize the necessity of tailored land use management practices to ensure sustainable soil health and productivity in these areas.

Keywords: Chemical properties, biological properties, enzyme activities, dehydrogenase activities, urease activities, land use systems

Introduction

Soil is a complex and living ecosystem, forms the foundation of terrestrial life. Its health is a product of balance among physical, chemical, and biological factors, such as soil texture, organic matter content, nutrient availability, pH, and the diversity and activity of soil microorganisms. These intricate components interact harmoniously to govern critical soil functions, including nutrient cycling, water retention, carbon storage, and the support of diverse life forms. Ensuring soil health is vital to securing the long-term sustainability of ecosystems and optimizing land use systems for the benefit of current and future generations (Tahat *et al*., 2020) [33].

Land use systems refer to the different ways in which land is managed for various purposes. These systems categorize land based on its primary use and activity and can vary widely due to geographical location, climate, soil conditions, and human interventions (Lagro, 2005) [18]. Different land use systems, spanning from natural ecosystems to intensive agricultural practices and urban developments, exert distinct pressures on soil health. Natural ecosystems, with their intricate web of interactions and minimal human intervention, tend to show higher soil biodiversity and nutrient cycling processes. Conversely, intensive agricultural systems, driven by the aim of maximum crop yields, may deplete soil nutrients, degrade soil structure, and diminish microbial diversity, resulting in soil degradation over time (Correia and Lopes, 2023; Rayne and Aula, 2020) [8, 27]. Soil degradation and declining fertility can lead to reduced crop yields, heightened susceptibility to erosion and flooding, and compromised water quality due to nutrient runoff. Furthermore, altered soil ecosystems can disrupt the delicate balance of greenhouse gas emissions, potentially exacerbating climate change. Globally, agricultural intensification and urban expansion are significant drivers of land use changes (Lambin and Meyfroidt, 2011) [19]. The relentless growth in population and economic demands has transformed natural habitats such as forests, grasslands, and wetlands into agricultural fields and urban landscapes (Bengtsson *et al*., 2019; Pilgrim *et al*., 2010; Bullock *et al*., 2011; Lemaire *et al*., 2011) [3, 26, 4, 20].

Intensive agricultural practices, including extensive plowing, monoculture cropping, and the excessive use of chemical fertilizers and pesticides, can accelerate soil degradation, reduce soil organic matter, and lead to a decline in soil biodiversity (Francaviglia *et al*., 2023) [9]. Consequently, soil health is compromised, affecting the soil's ability to sustainably support plant growth and provide essential ecosystem services.

To address the intricate challenges posed by various land use systems on soil health in the northern transect of Bangalore, scientific research was undertaken at the Department of Soil Science and Agricultural Chemistry from 2021 to 2023. This research aimed to investigate the impact of diverse land management practices on soil physical, chemical, and biological properties. Additionally, it is required to unravel the interconnected relationship between soil health and the array of land use systems, encompassing both natural ecosystems and traditional agricultural practices.

2. Materials and Methods

2.1 Site Description

To study the social-ecological transformation processes occurring in the interface between rural and urban areas in Bengaluru, we established two specific research areas, referred to as transects. These transects, namely the Northern and Southern transects, served as shared spaces for interdisciplinary investigations (Fig.1). The Northern transect is a rectangular-shaped area, measuring 5 kilometers in width and 50 kilometers in length (Fig. 2 and 3). Geographically, this transect is divided into two distinct sections: the lower part, encompassing urban areas, and the upper part, comprising rural villages (Hoffmann *et al*., 2017) [11]. For simplicity, we provide the specific coordinates marking the corners of the Northern transect in Bengaluru, as detailed in Table 1.

Table 1: Corner coordinates of the northern transects

N-Transect	
77.56452° E	13.06168° N
77.61002° E	13.06139° N
77.61119° E	13.40723° N
77.56321° E	13.40669° N

2.2 Site selection and soil Sampling

Following an initial survey, we selected various land use systems within the northern transect of Bengaluru. Subsequently to ensure comprehensive coverage, twenty surface soil samples were collected at a depth of 0-15 cm from horticulture, sericulture and organic farming land use systems. the collected soil samples were air-dried before being finely ground using a wooden pestle and mortar. Following this pre-processing, the samples were sieved through a 2 mm sieve. The chemical and biological properties of the soil samples were analyzed using the standard analytical procedures, as detailed in Table 2.

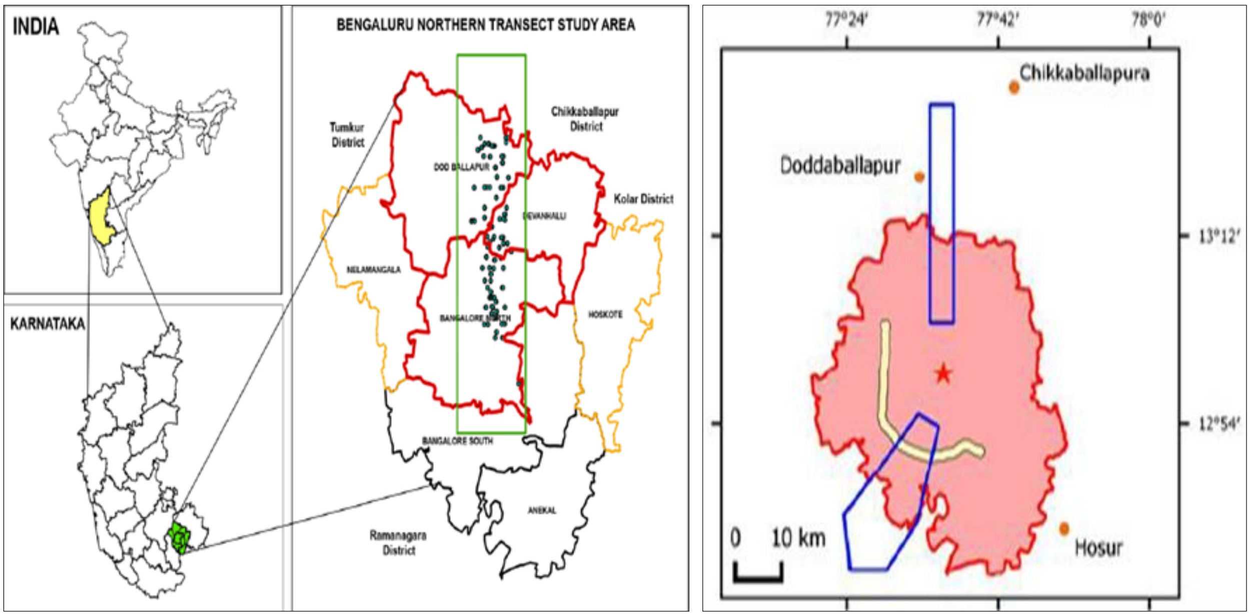

Fig 1: Study area

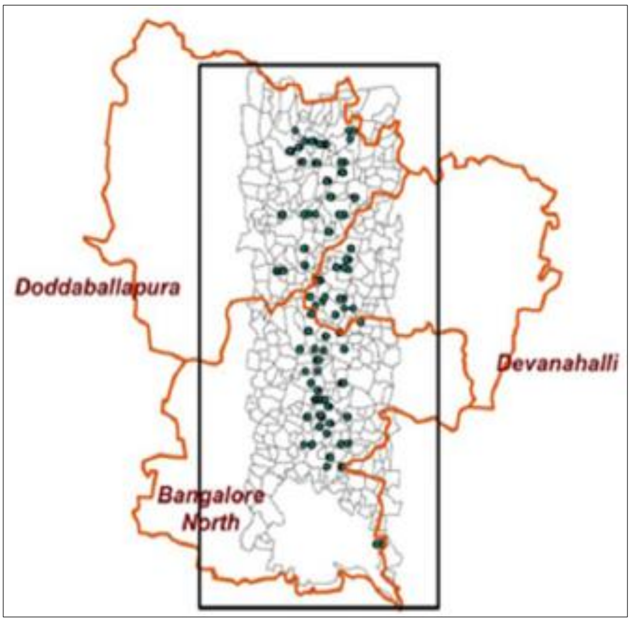

Fig 2: Study area village of the northern transect of Bengaluru

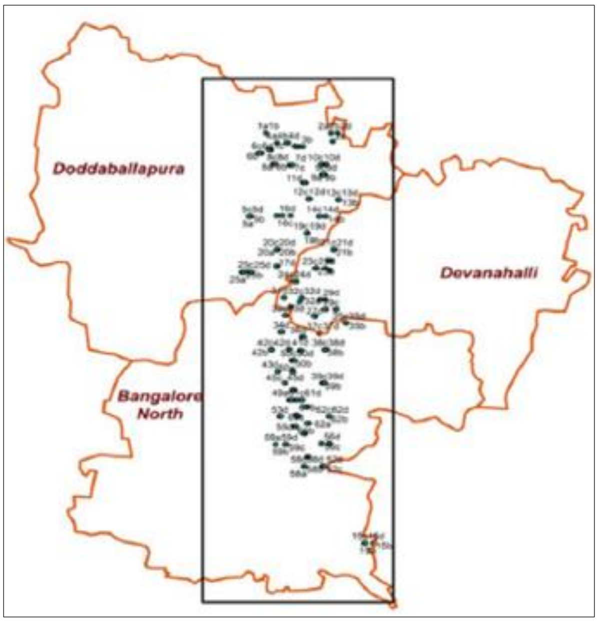

Fig 3: Grid points of study area

Table 2: Soil properties and methods adopted for analysis

Sl. No	Soil properties	Methods of analysis
1	pH	Potentiometric method (Jackson 1973) [12]
2	EC(dS/m)	Conductivity bridge (Jackson 1973) [12]
3	SOC(g/kg)	Wet digestion method (Jackson 1973) [12]
4	Available N(kg/ha)	Alkaline $KMnO_4$ method (Jackson 1973) [12]
5	Available P_2O_5	Colorimetric method (Jackson 1973) [12]
6	Available K_2O	Flame photometry (Jackson 1973) [12]
7	Exchangeable Ca [cmol (p+) kg^{-1}]	Versenate titration method (Jackson 1973) [12]
8	Exchangeable Mg [cmol (p+) kg^{-1}]	Versenate titration method (Jackson 1973) [12]
9	Available S (mg/kg)	Turbidimetry (Black 1965)
10	Available Zn (ppm)	DTPA extraction method (Lindsay and Norwell, 1978) [22]
11	Available Cu (ppm)	DTPA extraction method (Lindsay and Norwell, 1978) [22]
12	Available Mn (ppm)	DTPA extraction method (Lindsay and Norwell, 1978) [22]
13	Available Fe (ppm)	DTPA extraction method (Lindsay and Norwell (1978) [22]
14	Urease (µg NH^+_4 g^{-1} soil hr^{-1})	Spectrophotometric **(**Tabatabai and Bremner, 1970**)** [32]
15	Dehydrogenase (µg TPF g^{-1} of soil day^{-})	Spectrophotometric (Casida *et al.* (1964) [6]
16	Soil microbial biomass carbon and nitrogen	Chloroform fumigation and incubation method (Carter, 1991) [5]

2.3 Statistical analysis and data interpretation

One-way statistical analysis was used (Gopinath *et al.*, 2020) [10] for comparing soil properties among different land use systems in the northern transect of Bangalore. The level of significance used for determining the significant difference in the chemical and biological properties of different land use systems was $p<0.05$. Post-hoc tests were performed to identify specific differences between land use systems by using the least significant difference.

3. Results and Discussion

3.1. Soil pH, electrical conductivity (EC), and Soil organic carbon (SOC)

Within the observation area, it was observed that soil pH remained slightly acidic across the different land use systems (Table 3 and 4). This trend of reduced pH levels might be due to the presence of red soil, a characteristic feature resulting from the presence of granite parent material along the northern transect of Bangalore. Similar observations were reported by Shen *et al*. (2021). It also recorded that the soil pH of the horticulture (6.47), sericulture (6.26) and organic farming (6.25) land use systems are not significantly different.

In the context of soil electrical conductivity (EC) values, it was recorded that horticulture land use systems (0.44 dS m^{-1}) have significantly higher EC values compared to the sericulture (0.34 dS m^{-1}) and organic farming (0.32 dS m^{-1}) land use system. This salinity in the horticulture land use system might be due to the intensive utilization of inorganic fertilizer in the horticulture land use system compared to organic farming and sericulture land use systems. These findings were similar to the observations made by Sahrawat *et al.* (2014) [28], they also noted higher levels of soil EC in systems where inorganic nutrient management practices were used.

Significantly higher content of SOC was recorded from organic farming land use system ($1.07\%^{b}$) because in this system organic forms of fertilizers like farm yard manure, compost, *etc.* are added to the soil (Singh *et al.*, 2017) [30]. Continuous addition of organic material in the cultivated field may cause an increased level of organic carbon in the organic farming land use system (Ayoubi *et al*., 2014; Awotoye *et al.*, 2013) [1, 2]. Horticulture and sericulture land use systems have lower SOC contents of, 0.63^{c} and 0.59^{c} percent respectively.

Table 3: The range and mean value of Soil pH, soil EC and SOC in different LUSs

Soil parameters	Horticulture land use system (n=20)		Sericulture land use system (n=20)		Organic farming land use system (n=20)	
	Range	Mean	Range	Mean	Range	Mean
pH (1:2.5)	5.26-8.20	6.47	4.85-7.69	6.26	4.92-7.46	6.25
EC (1:2.5) (dSm^{-1})	0.10-0.92	0.44	0.19-0.60	0.34	0.10-0.67	0.32
OC (%)	0.52-0.71	0.63	0.42-0.91	0.59	0.51-1.86	1.07

Table 4: One-way analysis of Soil pH, soil EC and SOC in different LUSs

Soil parameters	Horticulture land use system ± SD (n=20)	Sericulture land use system ± SD (n=20)	Organic farming land use system ±SD (n=20)	Between land use systems	
				S.Em.	LSD* (p=0.05)
pH (1:2.5)	6.47±0.68	6.26±1.07	6.25±0.66	0.18	NS
EC (1:2.5) (dSm^{-1})	0.44^{a}±0.22	0.34^{b}±0.13	0.32^{b}±0.16	0.25	0.11
OC (%)	0.63^{b}±0.04	0.59^{b}±0.14	1.07^{a}±0.42	0.09	0.25

3.2 Primary nutrients (N, P and K)

A significantly higher level of available nitrogen content was recorded from the horticulture (312.35^{a} kg ha^{-1}) land-use systems (Table 5 and Table 6). Direct and extensive use of inorganic fertilizers like urea and DAP might increase the available nitrogen (ammonical and nitrate nitrogen) in the horticulture land use systems (Shivakumar, *et al*., 2020) [29]. Available nitrogen content in sericulture land use systems (286.33^{ab} kg ha^{-1}) and organic land use systems (252.74^{b} kg ha^{-1}) was on par with each other.

The mean value of the available phosphorus in different land use systems was 31.13 kg ha^{-1} in horticulture land use systems, 28.96 kg ha^{-1} in sericulture land use systems and 25.38 kg ha^{-1}in organic land use systems. A significant difference was recorded in the available phosphorus content of the different land use systems (Table 6). Significantly higher available phosphorus content was found in horticulture (31.13^{a} kg/ha) and sericulture (28.96^{a} kg/ha) land use systems than in organic farming land use systems (25.38^{b} kg/ha). This might be due to the application of available phosphorus-containing fertilizers (DAP, SSP, *etc.*) in the horticulture and sericulture land use systems. In organic farming land use systems, the farmers utilize organic materials like compost, FYM, *etc.* from which the release rate of available phosphorus will be less compared to the inorganic fertilizers (Kaiser *et al.*, 2012; Liang *et al.*, 2018) [14, 21].

The available potassium content did not differ significantly among the land use systems (Table 6). The recorded potassium content in horticulture, sericulture and organic farming land use systems were 287.22 kg/ha, 242.14 kg/ha and 252.62 kg/ha respectively.

3.3 Secondary nutrients (Ca, Mg, and S) and exchangeable Na:

The horticulture land use system has recorded a significantly higher content of exchangeable calcium (6.1^{a} meq/100 mg) compared to sericulture (4.7^{b} meq/100 mg) and organic farming (5.1^{ab} meq/100 mg) and use system. Farmers often apply calcium-rich liming materials more extensively in horticulture fields than in sericulture and organic farming land use systems. This increased usage of liming materials contributes to higher levels of exchangeable calcium in horticulture land use.

Table 5: The range and mean value of soil available macronutrients (N, P and K) (kg ha^{-1})

Soil parameters	Horticulture land use system (n=20)		Sericulture land use system (n=20)		Organic farming land use system (n=20)	
	Range	Mean	Range	Mean	Range	Mean
Available N (kg ha^{-1})	163.07-488.16	312.35	125.44-475.62	286.3	150.53-351.23	252.74
Available P_2O_5 (kg ha^{-1})	19.83-66.68	31.13	12.31-50.27	28.96	11.54-53.86	25.38
Available K_2O (kg ha^{-1})	158.19-622.41	287.22	108.30-518.78	242.1	85.75-539.48	252.62

Table 6: One-way analysis of soil available macronutrients (N, P and K) (kg ha^{-1})

Soil parameters	Horticulture land use system (n=20)	Sericulture land use system (n=20)	Organic farming land use system (n=20)	Between land use systems	
				S.Em.	LSD*
Available N (kg ha^{-1})	312.35^{a}±93.84	286.33^{ab}±103.12	252.74^{b}±59.65	17.90	47.93
Available P_2O_5 (kg ha^{-1})	31.13^{a}±11.97	28.96^{a}±11.10	25.38^{b}±11.87	2.36	6.64
Available K_2O (kg ha^{-1})	287.22±149.77	242.14±107.23	252.62±132.14	26.04	NS

The exchangeable magnesium content was significantly higher in horticulture land use system (3.0^{a} meq/100 mg) than in sericulture land (2.4^{b} meq/100 mg) and organic farming (2.7^{ab} meq/100 mg) land use systems. To satisfy the calcium (Ca) requirements in horticulture crops, farmers may use various liming materials however, the liming materials often contain a higher proportion of magnesium (Mg) along with calcium. For instance, dolomite, contains 12-30 percent Mg, while calcite lime has 0-2 percent Mg, and Magnesium limestone comprises 20-40 percent Mg. As a result, the increased usage of these liming materials could contribute to the higher magnesium levels in horticultural land use systems. also reported a similar trend. External application of the liming material is not practiced in the organic farming land use system this may be the reason for the reduced level of magnesium content in the soil.

Horticultural land use system has recorded significantly higher available sulfur, with mean values of 17.10 mg/kg. Sericulture and organic farming have recorded available sulfur content of 11.83 mg/kg and 9.53 mg/kg. Higher level of available sulphur in horticulture land use system may be due to the application of sulfur-containing fertilizers, such as ammonium sulfate or elemental sulfur (Moges *et al.*, 2013; Kaushik *et al.*, 2018) [23, 15].

There was no significant variation in sodium content in the soil, across different land use systems of the northern transect of Bangalore. The sodium content observed in various land use systems was 4.30 cmol/kg in the horticultural land use system, 4.77 cmol/kg in the sericulture land use system and 5.12 cmol/kg the in organic farming land use system. Non-significant differences of sodium content were recorded among different land use systems might be due to high leaching and run-off loss of the sodium from the soil (Pavithra *et al.*, 2021) [24]. Also, the irrigation water used in this area does not contain sodium ions, hence may not contribute to sodium ion buildup in horticulture, sericulture and organic farming land use systems (Tejashvini and Subbarayappa, 2022) [34].

Table 7: Secondary nutrients (Ca, Mg, and S) and exchangeable Na

Soil parameters	Horticulture land use system ± SD (n=20)	Sericulture land use system ± SD(n=20)	Organic farming land use system ±SD (n=20)	Between land use systems	
				S.Em.	LSD* (p=0.05)
Exchangeable Ca (meq $100g^{-1}$)	6.1^{a}±1.62	4.7^{b}±1.86	5.1^{ab}±1.52	0.44	1.25
Exchangeable Mg (meq $100g^{-1}$)	3.0^{a}±0.81	2.4^{b}±1.42	2.7^{ab}±0.75	0.22	0.62
Exchangeable Na (mg $100g^{-1}$)	4.30±3.05	4.77±2.19	5.12±3.26	0.68	NS
Available S (mg kg^{-1})	17.10^{a}±6.60	11.83^{ab}±18.68	9.53^{bc}±4.4	2.05	5.75

Table 8: One-way analysis of Secondary nutrients (Ca, Mg, and S) and exchangeable Na

Soil parameters	Horticulture land use system ± SD (n=20)		Sericulture land use system ± SD(n=20)		Organic farming land use system ±SD (n=20)	
	Range	Mean	Range	Mean	Range	Mean
Exchangeable Ca (meq $100g^{-1}$)	2.6-8.4	6.1	1.2-9.2	4.7	2.9-9.0	5.1
Exchangeable Mg (meq $100g^{-1}$)	1.3-4.2	3.0	0.6-4.6	2.4	1.5-4.5	2.7
Exchangeable Na (mg $100g^{-1}$)	1.09-9.96	4.30	0.18-10.87	4.77	1.23-8.51	5.12
Available S (mg kg^{-1})	10.87-35.87	17.10	00.18-74.28	11.83	04.35-21.27	9.53

3.4 Micronutrients (mg/kg)

Zinc content in the soils of horticulture, sericulture and organic farming was 1.05 mg/kg, 0.75 mg/kg and 0.71 mg/kg respectively. Whereas the iron content in the soils of different land use systems was 8.99 mg/kg in horticulture land use systems, 11.66 mg/kg in sericulture land use systems and 6.89 mg/kg in organic farming land use systems. Manganese levels recorded from horticulture, sericulture and organic farming were 5.03 mg/kg, 4.75 mg/kg and 4.16 mg/kg, respectively. Whereas copper content in the soils of agriculture, horticulture, forest, sericulture, organic farming, and barren land use systems was 3.43 mg/kg, 1.42 mg/kg and 1.37 mg/kg, respectively.

There were no significant differences in Mn and Zn content in the soil of different land use system under study. However, a significantly higher concentration of copper was recorded from the horticultural land use system. This might be due to the intensive use of copper-based fungicides, including Bordeaux mixture, Cheshunt compound, and Mancozeb, in the horticulture land use system than that of other systems (Zubrod *et al.*, 2019) [37]; Wightwick *et al.* (2008) [36]; Komarek *et al.* (2010) [16] reported that extensive use of copper-based agrochemical may increase the copper content in the soil.

The micronutrient contents of the soil are generally influenced by various soil parameters, including pH, organic matter (OM), and soil moisture content, as mentioned by Peterson, (1999) [25]. These factors play a significant role in determining the availability and uptake of micronutrients by plants in the soil.

Table 9: One-way analysis of soil available micronutrients (Zn, Fe, Mn, and Cu) (mg/kg)

Soil parameters	Horticulture land use system ± SD (n=20)	Sericulture land use system ± SD(n=20)	Organic farming land use system ±SD (n=20)	Between land use systems	
				S.Em.	LSD* (p=0.05)
Available Zn (mg kg^{-1})	1.05±0.73	0.75±0.65	0.71±0.64	0.12	NS
Available Fe (mg kg^{-1})	8.99^{b}±2.69	11.66^{a}±2.96	06.89^{c}±1.33	0.54	1.52
Available Mn (mg kg^{-1})	5.03±1.98	4.75±2.37	4.16±2.02	0.42	NS
Available Cu (mg kg^{-1})	03.43^{a}±2.89	01.42^{b}±0.56	01.37^{b}±0.96	0.30	0.84

3.6 Enzyme Activity (Dehydrogenase and urease activity)

Dehydrogenase activity (DHA) is widely used as a measure of microbial activity and biomass in the soil (Subhani *et al.*, 2001) [31]. A significant difference in dehydrogenase activity was recorded from different land use systems under study (Table 10 and Table 11). These variations might be due to variations in pH, temperature, organic matter content, microbial community and redox potential of the soil as reported by Trevors (1984) [35]. The dehydrogenase activities recorded from the organic farming land use systems (34.15 µg TPF g^{-1} soil 24 h^{-1}) were significantly higher compared to the other land use systems. This might be due to the use of compost, manure, and other organic amendments in the organic farming land use systems. Unlike synthetic fertilizers, these organic inputs do not harm or suppress microbial growth in the soil (Jenkinson and Powlson 1976) [13]. In horticulture (28.80 µg TPF g^{-1} soil 24 h^{-1}) and sericulture (23.55 µg TPF g^{-1} soil 24 h^{-1}) land use system, the recorded dehydrogenase activity was significantly lower compared to the organic farming land use systems. This might be due to the use of synthetic agrochemicals in in horticulture and sericulture land use systems. These synthetic inputs may negatively affect the microbial community in the soil and prolonged or excessive use of inorganic fertilizers may lead to imbalances in soil nutrients, which can also reduce microbial growth and activity (Trevors, 1984; Subhani *et al.*, 2001) [35, 31].

The urease enzyme (Urea amidohydrolase) is very important for the nitrogen cycle in the soil system (Kuscu, 2019) [17]. Urease activities from different land use systems (Table 10 and Table 11) under study did not differ significantly. Urease activity recorded from horticulture, sericulture and organic land use systems was 65.71 µg $NH4^+$-N g^{-1} soil h^{-1}, 65.32 µg $NH4^+$-N g^{-1} soil h^{-1}. of 64.91 µg $NH4^+$-N g^{-1} soil h^{-1}respectively.

3.7 Nitrogen fixers

The nitrogen-fixing bacterial count varied significantly among different land-use systems (Table 10). The nitrogen-fixing bacterial count from horticulture land use systems was 36x 10^{-4} cfu/g. Significantly higher numbers of nitrogen-fixing bacterial colonies (80x 10^{-4}cfu/g) were recorded on organic farming land use systems. The free-living nitrogen fixers in different land use systems depend on soil properties such as pH, EC, organic matter, and temperature. The variations in the soil properties among the different land use systems contribute to the differences in nitrogen fixer populations (Crecchio *et al.*, 2004) [7].

Table 10: One-way analysis of soil biological properties

Soil parameters	Horticulture land use system ± SD (n=20)	Sericulture land use system ± SD(n=20)	Organic farming land use system ±SD (n=20)	Between land use systems	
				S.Em.	LSD* (p=0.05)
Urease activity (µg NH_4^+-N g^{-1} soil h^{-1})	65.71±5.94	65.32±8.32	66.14±8.05	1.43	NS
Dehydrogenase Activity (µg TPF g^{-1} soil 24 h^{-1})	28.80^b±2.91	23.55^c±2.38	34.15^a±2.64	0.56	1.59
Nitrogen Fixers	36^b±10.23	18^c±6.84	80^a±12.57	2.02	5.66

4. Conclusion

In conclusion, the comparative analysis of chemical and biological properties in rural land use systems along the Northern transect of Bangalore has shed light on the state of soil health in this region. The study has uncovered noteworthy disparities in various soil properties, such as pH levels, organic matter content, macro and micro available nutrient levels, and biological characteristics, among different land use systems. These findings strongly suggest that the soil quality in this area is significantly affected by the range of land use and management practices employed. Understanding these variations in soil properties is crucial for sustainable land management and agricultural practices in the Northern transect of Bangalore. It provides valuable insights into how different land use practices impact soil health, which can inform decisions aimed at optimizing agricultural productivity, preserving natural resources, and promoting environmental sustainability.

Future research and land management strategies should consider these findings to develop tailored approaches for soil conservation and enhancement in this region, taking into account the specific needs and challenges associated with each land use system. Additionally, ongoing monitoring and assessment of soil properties will be essential to track changes over time and guide adaptive management practices to ensure the long-term health and productivity of the soils in this area.

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