Research Article
The J. Res. PJTAU 53 (3&4) 30-40, 2025

SOIL NUTRIENTS AND ORGANIC CARBON VARIATIONS IN FOREST AND PASTURE ECOSYSTEMS OF THE GODAVARI RIVER BELT, TELANGANA

SABOORA RANA, RAJESHWAR MALAVATH, M. SHANKARAIAH and BALAZZII NAAIIK RVT
College of Agriculture, PJTAU,Rajendranagar, Hyderabad

Date of Receipt: 15-09-2025 Date of Acceptance: 01-11-2025

ABSTRACT

This study investigates the variations in soil physico-chemical and chemical properties between forest and pasture land-use systems (LUS) in the Godavari River Belt of Nirmal District, Telangana to assess the soil fertility status. Soil samples from both LUS were analysed for pH, electrical conductivity (EC), organic carbon (OC), calcium carbonate ($CaCO_3$), macronutrients (N, P, K, S) and micronutrients (Fe, Mn, Cu, Zn, B).The soils of the study area are neutral to slightly alkaline (6.51-8.42), non-saline in nature (0.12- 0.80dS m^{-1})and medium to high in organic carbonstatus (7.3 -11.70 g kg^{-1}) in all land use systems.Results revealed that forest soils exhibited significantly higher OC (7.9 -11.1 g kg^{-1}), nitrogen (208.62 - 249.72 kg ha^{-1}), and micronutrient concentrations compared to pasture soils, attributed to greater organic matter input and minimal disturbance. In contrast, pasture soils showed slightly elevated pH (6.77 - 8.42) and $CaCO_3$ (4.21 - 5.36 g kg^{-1}), likely due to reduced organic turnover and grazing pressures.Strong positive correlations were observed between OC and nutrient availabilityindicating that nutrient levels are high due to presence of organic carbon,while pH and $CaCO_3$ negatively influenced micronutrient solubility. These findings underscore the critical role of forests in maintaining soil fertility through organic matter retention. The study highlights the need for sustainable pasture management practicessuch as organic amendments and controlled grazingto mitigate soil degradation in the Godavari River Belt.

Keywords: Soil fertility, land-use systems, organic carbon, macronutrients, micronutrients, Godavari River Belt.

Soil is a vital natural resource that sustains agricultural productivity, ecosystem stability, and biodiversity. Its physico-chemical and chemical properties are strongly influenced by land use systems (LUS), which alter organic matter content, nutrient cyclingand microbial activity (Lal, 2015).Forest ecosystem dynamics are intrinsically linked to soil characteristics, as soils mediate critical functions including water retention, nutrient cycling and root stabilization(Rajeshwar and Aariff khan, 2007). Forests and pastures represent two contrasting land-use types with distinct impacts on soil health, forests maintain high organic inputs and minimal disturbance, while pastures experience periodic grazing and biomass removal. Understanding these variations is crucial for sustainable land management, particularly in ecologically sensitive regions like the Godavari River Belt in Nirmal District, Telangana, where soil degradation due to land-use changes posses a growing concern. The Godavari River Basin is an agriculturally significant region where shifting land-use patternsparticularly deforestation for pasture expansionmay be affecting soil fertility. Forests typically enhance soil organic carbon, nitrogenand micronutrient availability due to continuous litter decomposition and minimal erosion (Dhaliwal *et al.,* 2023). In contrast, pasturelands often exhibit reduced SOC, increased bulk density and nutrient depletion due to grazing pressures and reduced organic inputs. Soilphysico-chemical and chemical properties vary with land use changes. Additionally, variations in pH, electrical conductivity (EC) and calcium carbonate ($CaCO_3$) content influence nutrient solubility, affecting crop productivity and ecosystem health. This study aims toevaluate variations in soil physico-chemical properties (pH, EC, OC, $CaCO_3$) between forest and pasture LUS,and assess differences in macronutrient (N, P, K, S) and micronutrient (Fe, Mn, Cu, Zn, B) availability. Further to analyse correlations between soil properties and nutrient dynamics to identify key fertility indicators.

MATERIAL AND METHODS

Description of the study area

The study was conducted in Nirmal District which is situated between 19.1153° of Northern Latitude and 78.5661° of Eastern longitude region in northern Telangana, India, situated on the Godavari River's alluvial plains within the Deccan Plateau. The area of the district is 3,845 $km^2$and is bordered by Adilabad, Komaram Bheem, Mancherial, Jagtial,

Email: sabooraranа11@gmail.com

Nizamabad, and Maharashtra's Nanded District, the area features a tropical wet and dry climate (Köppen Aw) with 1,084 mm annual rainfall (primarily monsoon-driven), temperatures ranging from 22.5°C to 35.5°C and relative humidity between 35-90%. The district's fertile soils and riverine ecology support diverse land-use systems, making it ideal for comparing forest and pasture soil dynamics.

Soil sampling, processing, and analysis

A total of 48 samples were collected from two depths*i.e*24 surface samples (0 - 15 cm) and 24subsurface samples (15 - 30 cm) in both forest and pasture land use systems (LUS). From each land use system, 24 samples were collected at every location using an auger and stored in polythene bags. The collected soil samples were air-dried in the shade, gently crushed, and sieved through a 2.0 mm sieve to obtain uniform representative samples. Soil samples were analysed for pH, EC, OC, $CaCO_3$, available macronutrients (N, P, K, S) and available micronutrients (Fe, Zn, Cu, Mn, B) by using standard procedures. Table. 1 shows the soil attributes and the analytical standard methods used.

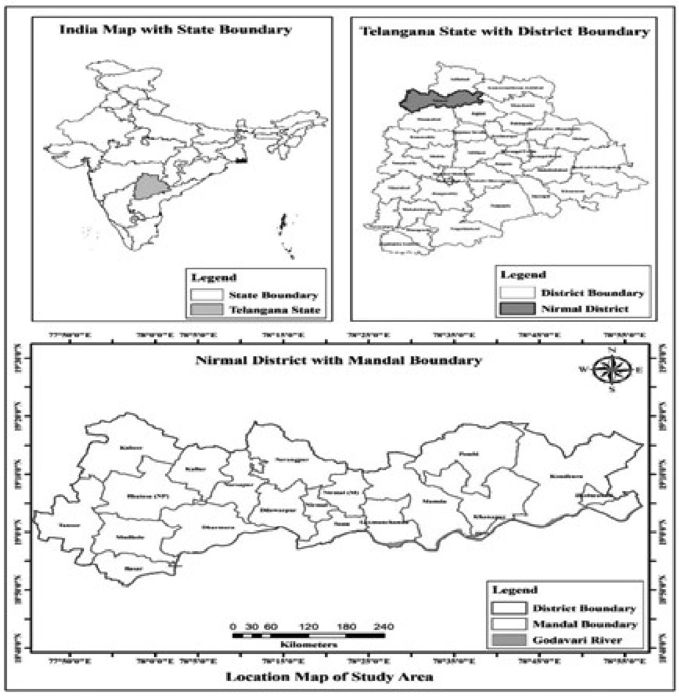

Fig 1. Location map of the study area

Table 1. Methods used to measure soil properties for soil quality.

Physico-Chemical Parameters	Method	References
1. Soil reaction (pH)	1:2.5 soil water suspension	Jackson (1973)
2. Electrical conductivity (dS m^{-1})	1:2.5 soil water suspension	Jackson (1973)
3. Organic carbon (g kg^{-1})	Wet oxidation method	Walkley and Black (1934)
4. Free calcium carbonate	Rapid titration method	Piper (1966)
Chemical Parameters		
1. Available Nitrogen (kg ha^{-1})	Alkaline $KMnO_4$ method	Subbiah and Asija (1956)
2. Available phosphorus (kg ha^{-1})	Olsen's extractant by ascorbic acid method	Olsen *et al*. (1954)
3. Available potassium (kg ha^{-1})	Neutral normal ammonium acetate method	Jackson (1973)
4. Available sulphur (mg kg^{-1})	Turbidimetry method	Chesnin and Yien (1950)
5.Available Micronutrients (mg kg^{-1})	DTPA method using AAS	Lindsay and Norvell (1978)
6. Available Boron(mg kg^{-1})	Hot water extractable B	Berger and Troug (1939)

Table 2. Soil Physico-chemical and chemical characteristics in different Land Use Systems in Godavari River Belt of Nirmal District of Telangana.

S.No	Location /mandal	Name of the village	Depth (cm)	pH (1:2.5)	EC (d Sm^{-1})	OC (g kg^{-1})	$CaCO_3$ (g kg^{-1})	Available macronutrients (kg ha^{-1}) N	P	K	S (mg kg^{-1})	Available micronutrients (mg kg^{-1}) Fe	Mn	Cu	Zn	B
Forest land use system																
1	Khanapur	Thimmapur	0-15	6.92	0.23	11.2	3.25	240.87	41.85	380.46	18.43	8.24	5.66	0.96	1.21	0.84
2			15-30	7.24	0.27	9.9	4.65	225.72	33.97	358.25	16.58	4.35	4.71	0.74	1.06	0.65
3		Iqbalpur	0-15	6.73	0.26	10.8	2.87	269.63	39.62	415.81	20.35	6.27	6.84	1.08	0.95	0.93
4			15-30	7.12	0.33	8.5	3.61	214.44	35.43	325.17	18.49	5.86	5.13	0.76	0.82	0.72
5		Gangaipet	0-15	7.18	0.27	10.7	3.52	256.48	45.61	360.3	16.84	8.49	4.89	0.64	1.13	0.78
6			15-30	7.35	0.31	8.8	4.12	218.26	41.28	353.74	14.23	6.28	4.63	0.43	1.03	0.46
7	Dasturabad	Mallapur	0-15	6.74	0.12	11.7	3.76	268.48	43.26	389.8	17.38	9.33	5.1	1.12	1.06	0.63
8			15-30	7.23	0.18	11.1	4.25	218.43	40.13	358.74	14.41	4.87	4.12	0.67	0.94	0.47
9		Erragunta	0-15	6.88	0.15	11.4	3.62	258.63	41.27	373.49	10.34	6.84	2.54	0.84	1.34	0.86
10			15-30	6.97	0.19	10.6	4.28	249.72	39.62	355.58	8.97	5.23	2.78	0.51	1.15	0.55
11		Akondapet	0-15	7.11	0.24	10.7	3.51	267.43	38.71	330.27	18.44	8.65	5.68	1.05	0.84	0.68
12			15-30	7.23	0.26	8.9	4.16	208.62	35.44	284.87	14.35	5.37	4.82	0.84	0.69	0.45
13	Mamda	Kappanpalle	0-15	7.54	0.28	11.5	3.75	261.43	37.28	373.02	16.86	7.45	4.29	1.11	0.88	0.76
14			15-30	7.82	0.33	10.3	4.1	241.54	34.25	324.35	12.17	5.44	3.21	0.97	0.72	0.57
15		Lachampur	0-15	7.06	0.38	9.7	4.12	257.58	43.28	299.62	13.24	6.28	4.65	1.34	0.97	0.67
16			15-30	7.24	0.4	8.7	6.24	234.25	40.25	245.78	11.51	4.56	5.67	0.89	0.74	0.43
17		Danthapalle	0-15	7.13	0.27	11.2	4.32	267.82	41	358.36	16.82	8.41	5.34	1.44	0.76	0.81
18			15-30	7.36	0.34	10.5	6.15	239.61	37.26	430.75	12.73	5.24	4.28	1.23	0.58	0.52
19	Dilawarpur	Dilawarpur	0-15	7.86	0.25	9.8	4.21	259.26	39.24	375.9	17.84	6.34	3.27	1.37	1.2	0.67
20			15-30	8.15	0.31	8.4	4.28	221.75	35.81	385.99	16.34	4.12	2.36	1.08	1.04	0.53
21		Kadili	0-15	6.98	0.14	10.7	3.56	254.36	42.06	334.69	16.27	6.77	3.49	0.96	1.11	0.54
22			15-30	7.24	0.21	9.1	4.11	237.46	38.61	399.78	13.54	4.11	3.25	0.73	1.02	0.38
23		Dilawarpur	0-15	6.76	0.27	8.8	3.62	261.58	42.15	315.47	13.28	5.46	4.67	1.64	1.05	0.58
24			15-30	7.27	0.37	7.9	5.28	247.13	38.17	349.3	10.28	3.24	2.77	1.11	0.67	0.37

Contd..

S.No	Location /mandal	Name of the village	Depth (cm)	pH (1:2.5)	EC (d Sm^{-1})	OC (g kg^{-1})	$CaCO_3$ (g kg^{-1})	Available macronutrients (kg ha^{-1}) N	P	K	S (mg kg^{-1})	Available micronutrients (mg kg^{-1}) Fe	Mn	Cu	Zn	B
Forest land use system																
Range	Surface soil		0-15	6.73-7.86	0.12-0.38	8.80-11.70	2.87-4.32	240.87-269.63	37.28-45.61	299.62-415.81	10.34-20.35	5.46-9.33	2.54-6.84	0.64-1.64	0.76-1.34	0.54-0.93
Mean				7.07	0.24	10.68	3.68	260.3	41.28	358.93	16.34	7.38	4.7	1.13	1.04	0.73
SD				0.34	0.07	0.86	0.41	7.99	2.3	33.26	2.76	1.22	1.18	0.28	0.17	0.12
Range	Subsurface soil		15-30	6.97-8.15	0.18-0.40	7.90-11.1	3.61-6.24	208.62-249.72	33.97-41.28	245.78-430.75	8.97-18.49	3.24-6.28	2.36-5.67	0.43-1.23	0.58-1.15	0.37-0.72
Mean				7.35	0.29	9.39	4.6	229.74	37.52	347.69	13.63	4.89	3.98	0.83	0.87	0.51
SD				0.32	0.07	1.04	0.84	13.61	2.51	49.36	2.72	0.85	1.07	0.24	0.19	0.1
Pasture land use system																
25	Soan	Madhapur	0-15	7.24	0.18	8.7	3.58	249.68	38.65	317.05	15.52	6.26	5.85	1.47	0.84	0.61
26			15-30	7.35	0.21	7.3	4.21	236.21	35.12	298.54	13.25	4.31	4.27	1.11	0.65	0.42
27		Pakpatla	0-15	6.58	0.25	8.5	3.64	226.53	34.27	346.51	16.53	5.61	5.33	1.28	0.79	0.47
28			15-30	6.84	0.27	7.9	4.37	209.54	31.05	312.34	12.42	4.25	3.45	1.04	0.62	0.41
29		Gamjal	0-15	7.38	0.34	9.4	4.62	273.14	28.68	355.13	15.68	7.44	5.89	0.98	0.89	0.45
30			15-30	7.64	0.38	8.2	4.85	243.68	26.15	317.55	13.25	5.23	3.65	0.86	0.81	0.31
31	Lamanchanda	Sangampet	0-15	6.51	0.14	8.8	4.17	226.75	37.61	324.83	17.54	6.13	4.75	0.75	0.96	0.67
32			15-30	6.89	0.18	8.1	4.86	216.84	32.42	299.13	12.49	4.85	3.22	0.34	0.57	0.55
33		Parpalle	0-15	7.16	0.24	8.4	4.76	251.73	38.19	311.24	16.84	5.21	5.64	0.61	0.73	0.72
34			15-30	6.77	0.29	8	5.36	244.65	35.17	280.9	11.64	4.36	3.17	0.43	0.61	0.63
35		Narsapur	0-15	7.24	0.25	9.2	3.57	237.26	40.28	346.85	15.86	7.55	4.28	0.58	0.82	0.51
36			15-30	7.29	0.22	8.9	5.31	207.56	38.59	314.26	13.52	4.13	2.65	0.34	0.68	0.43
37	Mamda	Mamda	0-15	6.98	0.16	8.6	4.62	259.61	41.26	333.28	15.26	6.24	4.32	0.82	0.95	0.66
38			15-30	7.23	0.28	7.8	5.33	225.14	37.18	310.85	12.84	4.98	3.76	0.46	0.66	0.57
39		Ponkal	0-15	7.14	0.23	9.7	2.74	227.15	39.58	297.36	13.62	5.14	2.53	1.34	0.87	0.53
40			15-30	7.53	0.27	8.7	4.32	184.26	37.45	249.68	11.45	3.26	1.07	1.08	0.81	0.42

Contd..

S.No	Location /mandal	Name of the village	Depth (cm)	pH (1:2.5)	EC (d Sm^{-1})	OC (g kg^{-1})	$CaCO_3$ (g kg^{-1})	Available macronutrients (kg ha^{-1})			S (mg kg^{-1})	Available micronutrients (mg kg^{-1})				
								N	P	K		Fe	Mn	Cu	Zn	B
Pasture land use system																
41	Dilawarpur	Lolam	0-15	8.36	0.21	8.9	3.84	234.18	37.43	325.44	15.66	5.77	2.31	1.27	1.08	0.58
42			15-30	8.42	0.26	8.2	4.76	214.26	35.14	298.63	13.57	4.26	0.19	0.94	0.85	0.47
43		Sirgapur	0-15	7.18	0.27	8.6	3.86	211.37	42.16	358.96	14.25	6.48	4.28	0.76	0.94	0.38
44			15-30	7.53	0.32	7.5	4.25	195.26	40.27	313.25	14.53	3.25	2.43	0.43	0.81	0.34
45	Khanapur	Sathnapalle	0-15	7.65	0.25	8.4	3.79	204.38	41.28	321.66	13.66	5.96	5.61	1.36	0.89	0.48
46			15-30	7.96	0.61	7.3	4.31	186.57	39.15	278.91	12.64	3.46	3.11	1.13	0.73	0.41
47		Mastan Yellapur	0-15	6.85	0.79	8.8	3.78	249.44	37.46	333.15	14.56	6.78	2.44	0.95	1.14	0.47
48			15-30	7.31	0.54	7.9	5.27	224.36	34.52	280.73	12.38	4.56	1.84	0.44	0.81	0.35
Range	Surface soil		0-15	6.51-8.36	0.14-0.79	8.40-9.7	2.74-4.76	204.38-273.14	28.68-42.16	297.36-358.96	13.62-17.54	5.14-7.55	2.31-5.89	0.58-1.47	0.73-1.14	0.38-0.72
Mean				7.19	0.28	8.83	3.91	237.6	38.07	330.96	15.42	6.21	4.44	1.01	0.91	0.54
SD				0.49	0.17	0.41	0.56	19.97	3.67	18.44	1.23	0.77	1.35	0.32	0.12	0.1
Range	Subsurface soil		15-30	6.77-8.42	0.18-0.61	7.3-8.9	4.21-5.63	184.26-244.65	26.15-40.27	249.68-317.55	11.45-14.53	3.25-5.23	0.19-4.27	0.34-1.13	0.57-0.85	0.31-0.63
Mean				7.4	0.32	7.98	4.77	215.69	35.18	296.23	12.83	4.24	2.73	0.72	0.72	0.44
SD				0.47	0.13	0.49	0.46	20.38	3.92	20.24	0.86	0.65	1.19	0.33	0.1	0.1

RESULTS AND DISCUSSION

Soil physico-chemical properties

Soils wereneutral to slightly alkaline and ranges from 6.51- 8.46 in both land use systems. pH values for surface soils ranges from6.51-8.36 (7.19) in pasture LUS and 6.73-7.86 (7.07) in forest LUSand in subsurface soils it ranged from 6.97 - 8.15 (7.35) in forest LUS and 6.77-8.42 (7.40) in pasture LUS,respectively (Table 2).The lower pH observed in forest LUS, compared to pasture, due to accumulation of more organic matter. As this organic material decomposes, it releases organic acids, which contribute to the reduction in soil pH (Chandel *etal*. 2018). Soil pH was recorded more in subsurface soils as compared to surface soils in bothLUSs might be due to poor content of organic matter, leaching and accumulation of basic cations in subsurface layers of soil. Similar findings were observed by Rajeshwar *et al*. (2024).

The soils were non saline in nature and the electrical conductivity of the soils ranged from 0.12 to 0.98 dSm^{-1} in all LUSs. The EC values for surface soils ranges from 0.14 - 0.79 (0.28dS m^{-1}) in pasture LUS, 0.12-0.38 (0.24dS m^{-1}) in forest LUS andin subsurface soils it ranged from 0.18 - 0.40 (0.29 dS m^{-1}) in forest LUS and 0.18 - 0.61 (0.32 dSm^{-1}) in pasture LUS, respectively (Table 2). Forest soils exhibit low EC due to minimal disturbances and limited external inputs, relying predominantly on natural nutrient cycling.Theresults are similar with the findings of Apoorva *et al.* (2021) and Kaur *et al.* (2021).

The organic carbon content ranged from 2.9 to 11.7 g kg^{-1} in all LUSs. Soil OC in surface soils varied from 8.80-11.70 (10.68 g kg^{-1}) in forest LUS, 8.40-9.7 (8.83 g kg^{-1}) in pasture LUS,respectively and in subsurface soils it ranged from 7.9 - 11.1 (9.39 g kg^{-1}) in forest LUS and 7.3 - 8.9 (7.98 g kg^{-1}) in pasture LUS. (Table 2). The soil OC was found higher under forest land and lowest under cotton land. Higher values of OC in forest LUS can be attributed to high biomass production and organic matter produced by vegetation is returned back to the soil and was not disturbed by the tillage. Comparable outcomes were attained with Chandel *et al.* (2018) and Bhunia *et al.* (2018). Soil OC was recorded high in surface soils than subsurface soils.

The Calcium carbonate content ranged from 2.58 to 8.95 g kg^{-1} in all LUSs. Calcium carbonate for surface soils varied from 0.18-0.34 (0.27 g kg^{-1}) in pasture LUS, 3.62-6.53 (5.15 g kg^{-1}) in forest LUSand in subsurface soils it ranged from 3.61 - 6.24 (4.60 g kg^{-1}) in forest LUS and 4.21 - 5.36 (4.77 g kg^{-1}) in pasture LUS,respectively (Table 2). In both land use systems $CaCO_3$ was recorded high in subsurface soils than surface soils due to leaching of salts from surface layers and their deposition in subsurface soil layers. These results were in conformity with the Sebnie *et al.* (2021) and Regasa and Lishan (2023).

Available Macronutrients (kg ha^{-1})

Available nitrogen for surface soils under different LUSs varied from 240.87-269.63 (260.30 kg ha^{-1}) in forestLUS, 204.38-273.14 (237.60 kg ha^{-1}) in pastureLUSand in subsurface soilsit ranged from 208.62-249.72 (229.74 kg ha^{-1}) in forest LUS and 184.26 -244.65 (215.69 kg ha^{-1}) in pasture LUS. Forest LUS has higher soil N content might be due to leaf litter and exudates produced by vegetation and their associated microbes can affect the rate of mineral dissolution which contributes to higher N availability (Sardar *et al.* 2023). Soil N was recorded high in surface soils than subsurface soils.

Available phosphorus for surface soils varied from 37.28-45.61 (41.28 kg ha^{-1}) in forest, 28.68-42.16 (38.07 kg ha^{-1}) in pastureand in subsurface soils itranged from 33.97 - 41.28 (37.52 kg ha^{-1}) in forest LUS and 26.15 - 40.27 (35.18 kg ha^{-1}) in pasture LUS, respectively (Table 2). The high content of OM in case of forest and pasture LUSs due to release of organic anions on decomposition which form chelates with Fe and Al leads to formation of phosphorus-rich soil aggregates and make the P available. The result resembles to the findings of Maqbool *et al.* (2017). In both land use systems, soil P was recorded high in surface soils than subsurface soils due to higher content of OM in the surface layer (Dhaliwal *et al.,* 2019).

Available potassium for surface soils varied from 299.62-415.81 (364.72 kg ha^{-1}) in forest, 297.36-358.96 (330.96 kg ha^{-1}) in pasturein subsurface soils itranged from 245.78 - 430.75 (347.69 kg ha^{-1}) in forest LUS and 249.68 - 317.55 (296.23 kg ha^{-1}) in pasture LUSrespectively (Table 2). Among both land use systems forest land recorded highest potassium followed by pasture land (Gandhe, 2015).

Available sulphur for surface soils varied from 10.34-20.35 (16.34 mg kg^{-1}) in forest, 13.62-17.54 (15.42 mg kg^{-1}) in pasture and in subsurface soils itranged from 8.97 - 18.49 (13.63 mg kg^{-1}) in forest LUS and 11.45 - 14.53 (12.83 mg kg^{-1}) in pasture LUS,respectively (Table 2). Forest LUSs have higher content of available sulphurdue to presence of organic matter in soils. In all land use systems soil available sulphur was recorded high in surface soils than subsurface soils. Similar results were recorded by Gurudev *et al.* (2024).

Available micronutrients (mg kg^{-1})

Zn content under different land use systems for surface soils varied from 0.76-1.34 (1.04 mg kg^{-1}) in forest, 0.73-1.14 (0.91 mg kg^{-1}) in pasture and in subsurface soils ranged from 0.58 - 1.15 (0.87 mg kg^{-1}) in forest LUS and 0.57 - 0.85 (0.72 mg kg^{-1}) in pasture LUS,respectively (Table 2). Zinc availability recorded highest in forest land due to stable organic matter content and lower soil disturbance (Rudani*et al*., 2018).

Cu content under different land use systems for surface soils varied from 0.64-1.64 (1.13 mg kg^{-1}) in forest, 0.58-1.47 (1.01 mg kg^{-1}) in pasture and in subsurface soils it ranged from 0.43 - 1.23 (0.83 mg kg^{-1}) in forest LUS and 0.34 - 1.13 (0.72 mg kg^{-1}) in pasture LUS,respectively (Table 2). Forest land generally maintains sufficient copper levels, sustained by the continuous decomposition of organic matter and the stability of soil pH and organic matter enhances Cu²z solubility through chelation and complexation with organic acids (Alaie*et al.* 2020). However, high pH and $CaCO_3$ reduce copper availability by forming insoluble compounds like Cu(OH), and $CaCO_3$ (Meena *et al.,* 2017).

Fe content under different land use systems for surface soils varied from 5.46-9.33 (7.38 mg kg^{-1}) in forest, 5.14-7.55 (6.21 mg kg^{-1}) in pasture and in subsurface soilsranged from 3.24 - 6.28 (4.89 mg kg^{-1}) in forest LUS and 3.25 - 5.23 (4.24 mg kg^{-1}) in pasture LUS,respectively (Table 2). The iron availability tends to be higher in forest land use systems due to the high organic matter content and minimal soil disturbance. Similar results were observed by Dhaliwal *et al*. (2023).

Mn content under different land use systems for surface soils varied from 2.54-6.84 (4.70 mg kg^{-1}) in forest, 2.31-5.89 (4.44 mg kg^{-1}) in pasture and in subsurface soilsit ranged from 2.36 - 5.67 (3.98 mg kg^{-1}) in forest LUS and 0.19 - 4.27 (2.73 mg kg^{-1}) in pasture LUS. In forested land, high soil organic matter and biodiversity due to less soil disturbance could contribute to high Mn concentration (Onwudike*et al*., 2016).

B content under different land use systems for surface soils varied from 0.54-0.93 (0.73 mg kg^{-1}) in forest, 0.38-0.72 (0.54 mg kg^{-1}) in pasture and in subsurface soilsranged from 0.37 - 0.72 (0.51 mg kg^{-1}) in forest LUS and 0.31 - 0.63 (0.44 mg kg^{-1}) in pasture LUS,respectively (Table 2). Such variations in extractable boron would have resulted due to the input from agricultural activities such as livestock manure, fertilizers and agrochemical sprays (Chandel *et al.,* 2018).The higher amount of DTPA extractable Fe, Mn, Zn, Cu and available B in the surface layer was due to the higher accumulation of organic matter content in the surface soil.

Correlation between physico-chemical properties and available macro nutrients and micronutrients

Soil pH and OC are the most critical factors influencing the availability of macro and micronutrients in the soil. A significant and positive correlation of available nitrogen was observed with organic carbon (r = 0.578**), whereas it was significantly and negatively correlated with pH (r = -0.320*)(Table 3).Similar results were observed by Sahu *et al*. (2022). A significant and positive correlation of phosphorus was observed with organic carbon (r = 0.405**)due to presence of more than 50% of P in organic forms and after the decomposition of organic matter, humus is formed which forms complex with Al and Fe and that is a protective cover for P-fixation with Al and Fe, thus reduce P adsorption/ fixation (Singh *et al*., 2014), whereas it was significantly and negatively correlated with $CaCO_3$ (r = -0.346*) (Table 3).This is because at higher pH, calcium precipitates with P as Ca-phosphate and reduce P availability. A significant and positive correlation of potassium was observed with organic carbon (r = 0.604**). A significant and positive correlation of sulphur was observed with organic carbon (r = 0.346*), whereas it was significantly and negatively correlated with $CaCO_3$ (r = -0.504**)(Table 3)which is consistent with the findings reported by Singh *et al.* (2014).

Table 3. Pearson's correlation matrix of surface soils for various physico-chemical properties and chemical parameters

	pH	EC	OC	$CaCO_3$	N	P	K	S	Fe	Mn	Cu	Zn	B
pH	1												
EC	0.187	1											
OC	-0.228	-0.336*	1										
CaCO3	0.175	0.232	-0.382**	1									
N	-0.320*	-0.155	0.578**	-0.188	1								
P	-0.193	-0.203	0.405**	-0.346*	0.175	1							
K	-0.112	-0.239	0.604**	-0.268	0.459**	0.209	1						
S	-0.104	-0.196	0.346*	-0.504**	0.312*	0.149	0.421**	1					
Fe	-0.308*	-0.205	0.684**	-0.497**	0.654**	0.371**	0.442**	0.579**	1				
Mn	-0.457**	-0.198	0.301*	-0.224	0.421**	0.178	0.281	0.553**	0.544**	1			
Cu	0.132	0.012	0.195	-0.346*	0.293*	0.127	0.125	0.188	0.209	0.211	1		
Zn	-0.050	-0.134	0.514**	-0.539**	0.359*	0.463**	0.450**	0.283	0.453**	0.003	0.140	1	
B	-0.303*	-0.330*	0.632**	-0.408**	0.572**	0.372**	0.395**	0.541**	0.601**	0.438**	0.174	0.393**	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

A significant and positive correlation of iron was observed with organic carbon (r = 0.684**), whereas it was significantly and negatively correlated with pH (r = -0.308*) and $CaCO_3$ (r = -0.497**)(Table 3).The decline in Fe availability with increasing pH is due to the oxidation of Fe^2z to Fe^3z , which tends to precipitate as insoluble iron hydroxides (Sahoo *et al.*, 2020) and (Sen *et al.,* 2017). A significant and positive correlation of manganese was observed with organic carbon (r = 0.301*), whereas it was significantly and negatively correlated with pH (r = -0.457**)(Table 3).As pH rises, the soluble Mn^2z is converted into water-insoluble higher oxidation states such as Mn^3z or Mnt z , and thus less available for plant uptake (Baruah *et al.,* 2014). A significant and positive correlation of copper was observed with available nitrogen (r = 0.293*), whereas it was significantly and negatively correlated with $CaCO_3$ (r = -0.346*)(Table 3). A significant and positive correlation of zinc was observed with organic carbon (r = 0.514**), whereas it was significantly and negatively correlated with pH (r = -0.050)and $CaCO_3$ (r = -0.539**).Zinc exhibited a negative correlation with soil pH, suggesting that higher pH levels contribute to the formation of calcareous or alkaline soils. This may be due to the precipitation of zinc as $ZnCO_3$ or the formation of insoluble calcium zincate, both of which reduce zinc availability in the soil. A significant and positive correlation of boron was observed with organic carbon(r = 0.632**), whereas it was significantly and negatively correlated with pH (r = -0.303*), EC (r = -0.330*) and $CaCO_3$ (r = -0.408**)(Table 3).The availability of boron was enhanced due to the formation of stable diol complexes with organic matter. This finding corroborates the results ofAmritanshu *et al*. (2023).

CONCLUSION

Macronutrients (N, P, K, S) were more abundant in forest soils, correlating strongly with organic carbon, while CaCOƒ negatively impacted P and S availability.Micronutrients (Fe, Mn, Cu, Zn, B) were more available in forest soils, with organic matter playing a crucial role in their retention and solubility.In contrast, pasture soils showed slightly higher pH and $CaCO_3$ content but lower nutrient retention, likely due to reduced organic inputs and periodic grazing pressures.Soil pH was lower in forest soils than in pastureinfluenced by organic acid release from decomposing biomass.

Surface soils had better soil quality as the availability of nutrients is higher in surface soil compared to subsurface soils because the surface soils had high organic matter content.

Sustainable land management in pasture systems should focus on organic matter enrichment (e.g., manure application, agroforestry) to enhance nutrient retention. Forest conservation is vital for maintaining long-term soil fertility and ecological balance, given its superior nutrient cycling capabilities.

REFERENCES

Alaie, T.A., Gupta, R and Sharma, V. 2020. Spatial distribution of available micronutrient status under different land use systems of district Doda, J&K. *Journal of Soil and Water Conservation*. 19(3): 317-321.

Amritanshu, S.P., Tyagi, A.K., Srivastava, A.J.A.Y.A and Pathak, A.N.A.N.D. 2023. Status of some extractable macro-and micro-nutrients in the soils of Dehradun district of Uttarakhand. *Annals of Plant and Soil Research*. 25(2): 221-229.

Apoorva, M.R., Padmaja, G., Sharma, S., Triveni, S and Rekha, K.B. 2021. Active and passive soil organic carbon pools as affected by different land use patterns in red soils of Vikarabad District, Telangana, India. *International Journal of Environment and Climate Change.* 11(12): 605-616.

Baruah, R., Thiyageshwari, S., Mani, S., Veelu, V and Stalin P. 2014. Distribution of available iron, manganese, zinc, copper and boron in soils of Cuddalore district of Tamil Nadu. *Journal of the Indian Society of Soil Science*. 62(3): 288–92.

Berger, KC, Troug E. Boron determination in soils and plants. Ind. Eng. Chem. 1939; 11:540-545

Bhunia GS, Shit PK, Maiti R. 2018. Comparison of GIS-based interpolation methods for spatial distribution of soil organic car bon (SOC). Journal of the Saudi Society of Agricultural Sciences. 17:114-126.

Chandel, S., Hadda M. S and Mahal. A.K. 2018. Soil quality assessment through minimum data set under different land uses of submontane Punjab. *Communications in Soil Science and Plant Analysis.* 49: 658-674.

Chesnin, L and Yien, C. 1950. Turbidimetric determination of available sulphates. *Soil Science Society of America Journal.* 15: 149-151.

Dhaliwal, S.S., Naresh, R.K., Mandal, A., Walia, M.K., Gupta, R.K., Singh, R and Dhaliwal, M.K. 2019. Effect of manures and fertilizers on soil physical properties, build-up of macro and micronutrients and uptake in soil under different cropping systems: a review. *Journal of Plant Nutrition*. 42(20): 2873-2900.

Dhaliwal, S.S., Sharma, V., Shukla, A.K., Kaur, J., Gupta, R.K., Verma, V., Kaur, M., Singh, V.K and Singh, P. 2023. Interactive effect of land use systems on depth-wise soil properties and micronutrients minerals in North-Western, India. *Heliyon*. 9(2).

Gandhe, A. 2015. A study of macronutrients in soils of different places around Indore, MP, India. *Research Journal of Chemical Sciences*. 5: 53-56.

Gowthamchand, Dhaliwal, S.S., Sharma, V., Verma, G., Singh, J and Kaur, M. 2023. Variation of physico-chemical properties among different soil orders under different land use systems of the majha region in north-western India. *Sustainability*. 15(6): 4779.

Gurudev, D., Naidu, M.V.S., Vasu, D., Reddy, G.K and Leelavathy, G.P. 2024. Characterization, Classification and Evaluation of Soils in Semi-Arid Ecosystem of Karvetinagram Mandal of Chittoor District, Andhra Pradesh. *Journal of the Indian Society of Soil Science*. 72(4). 365-376.

Jackson, M.L. 1973. Soil Chemical Analysis. Prentice Hall of India (Pvt.) Ltd., New Delhi. 1-498.

Kaur, T., Sehgal, S.K., Singh, S., Sharma, S., Dhaliwal, S.S and Sharma, V. 2021. Assessment of seasonal variability in soil nutrients and its impact on soil quality under different land use systems of lower Shiwalik foothills of Himalaya,India. *Sustainability*. 13(3): 1398.

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability*, 7(5), 5875-5895.

Lindsay, W.L and Norvell, W.A. 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of American Journal*. 43: 421- 428.

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

Meena, R.S., Rao, S.S., Natarajan, A., Hegde, R and Singh, S.K., 2017. Available micronutrients in soils of chikkarsinkerehobli of maddur taluk, mandya district of karnataka. *Journal of Plant Development Sciences*. 9(3): 229-233.

Olsen, S.R., Cole, C.V., Watanabe, F.S and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *Circular of United States Department of Agriculture.* 939.

Onwudike, S.U., Onweremadu, E.U., Ihem, E.E., Agim, L.C., Osisi, A.F., Osuaku, S.K and Azuh, P.O. 2016. Evaluation of micronutrient status of soils under three land use types in Oyigbo, River State, Nigeria. *Futo Journal Series.* 2(1): 32-40.

Piper, C.S. 1966. Soil and plant analysis. *Inter Science publication*. Inc. New York.

Rajeshwar, M., Thirupati, I., Shiva, K., Nagaraju, A., Sravanthi., Kumar, Bollaveni. 2024. Soil characteristics and available nutrient status of surface and sub-surface soils of KVK, bellampalli, mancherial for sustainable land use planning. *International Journal of Research in Agronomy*. 7: 774 - 779.

Rajeshwar, M and M. A. A. Khan. 2007. Distribution of available macro and micro nutrients in soil profiles of forest area of Nizamabad, India. *An Asian journal of soil science*.2 (2): 1-5.

Regasa, A and Lishan, T. 2023. A Comparative Analysis of Morpho-Physicochemical Properties of Soils of Ifa Galano Micro-Watershed, South-West Ethiopia. *Russian Agricultural Sciences*. 49(4): 413-429.

Rudani, K, P Vishal and P Kalavati. 2018. The importance of zinc in plant growth-A review. *International Research Journal of Natural and Applied Sciences*. 5 (2): 38-48.

Sahoo, J., Dinesh, B.M., Anil, A.S and Raza, M. 2020. Nutrient distribution and relationship with soil properties in different watersheds of Haryana. *Indian Journal of Agricultural Sciences*. 90(1): 172-7.

Sahu, M., Nisab, M.C and Mondal, S. 2022. Availability of macronutrients & sulphur and their relationship with physico-chemical properties in lateritic soils of Birbhum district, West Bengal. *International Journal of Economic Plants*. 9(3): 260-263.

Sardar, M.F., Younas,F., ZUR Farooqi and Y Li. 2023. Soil nitrogen dynamics in natural forest ecosystem: a review. *Frontiers in Forests and Global Change*. 6: 1144930.

Sebnie, W., Adgo, E and Kendie, H., 2021. Characterization and classification of soils of zamra irrigation scheme, northeastern Ethiopia. *Air, Soil and Water Research*. 14, p.11786221211026577.

Sen, A., Zaidi, S.F.A and Kumar, S. 2017. Status of available macro and micro nutrients and their correlation in soils of Eastern Plain Zone, Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry*. 6(6S): 270-3.

Singh, Y.P., Raghubanshi, B.P.S., Tomar, R.S., Verma, S.K and Dubey, S.K. 2014. Soil fertility status and correlation of available macro and micronutrients in Chambal region of Madhya Pradesh. *Journal of the Indian Society of Soil Science*. 62(4): 369-375.

Subbaiah, B.V and Asija, C.L. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Current Science*. 25: 32.

Walkley, A and Black, C.A. 1934. Estimation of organic carbon by chromic acid titration method. *Soil Science*. 37: 29-38.