Annals of Plant and Soil Research 25 (1): 31-39 (2023)
https://doi.org/10.47815/apsr.2023.10232

Assessing the physico-chemical and biological properties of soil under different land use types in southern transect of Bengaluru, Karnataka-India

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Received: December, 2022; Revised accepted, January, 2023

ABSTRACT

Soil is key resources upon which the functioning of all biological land use depends, and the most important component of sustainable agriculture with this view the study was conducted to assess physico-chemical and biological properties of soil under different land use types in southern transect of Bengaluru. Fifty soil samples were collected from each land use system viz agriculture, horticulture, mulberry and plantation land use. The soil was examined for various physico-chemical and biological properties including sand, silt, clay, soil pH, organic carbon (OC), electrical conductivity (EC), available nitrogen (N), phosphorus (P) and potassium (K), exchangeable calcium (Ca) and magnesium (Mg), sulphur (S), micronutrients (Zn, Fe, Mn, Cu and B) and heavy metals (Cd, Cr, Ni and Pb) and dehydrogenase activity (DHA). The results of the experiment reveled that soil pH varies from strongly acidic (4.23) to strongly alkaline (8.56), low (0.39 dS m^{-1}) to high (0.88 dS m^{-1}) EC content. Whereas OC content under different land use systems was in the medium range. The significantly higher soil OC, available N, P_2O_5 and K_2O recorded in agriculture land use. The exchangeable Ca (10.71 c mol (p^+) kg^{-1}) and Mg (7.96 c mol (p^+) kg^{-1}) recorded significantly higher in agriculture land use. Plantation land use marked significantly higher Fe (12.99 ppm) and Mn (8.51 ppm) contents followed by mulberry (12.16 ppm and 8.23 ppm), Whereas Zn and B were found high in agriculture land use system (0.80 ppm and 0.85 ppm) compare to other land use systems. Heavy metals (Cr, Pb and Ni) were found non-significant. Whereas Cd was found significantly different among the land-use system and found high in horticulture land use system (0.049 ppm). Conclusively, land use change affects soil physico-chemical and biological properties.

Keywords: Soil properties, land use systems and southern transect of Bengaluru

INTRODUCTION

Soil is the foundation resource for nearly all land uses, and the most important element in sustainable agriculture (Mulugeta and Karl 2010). Soil modification due to changes in land use types and patterns is a major threat to the sustainable productivity of the soil (Manpoong and Tripathi 2019). Land use change is one of the most important environmental changes affecting the biodiversity and function of ecosystems (Ferreira *et al.* 2016). It affects basic processes such as erosion, soil structure, nutrient recycling and carbon sequestration (Yoseph *et al.* 2017) and it greatly influences physico-chemical properties (Paz-Kagan, *et al.* 2014) and affects the nutrient dynamics and supply (Agniva *et al.* 2018). Land use change alters biodiversity and soil quality and thus affects ecosystem functions (Yoseph *et al.* 2017). Intensification of agriculture by the addition of mineral fertilizers in India largely limited to nitrogen (N), phosphorus (P) and potassium (K) and the application of urban compost and irrigation partly with waste water affect physico-chemical and biological properties of soils and thus their capacity to synchronize nutrient supply and demand in cropping systems. The process of urbanization has led to shift in land use system, farmers instead of growing agriculture crops they started growing commercial crops with use of chemical fertilizers to get higher returns, in long run which is leading to soil acidity and imbalance of nutrients and further drastic reduction in the production of crops and soils become unsuitable for crop production. However, achieving a balance between agricultural practice and conservation of natural resources is a necessary goal for development of sustainable agricultural systems. The process of urbanization has led to shift in land use system, farmers instead of growing agriculture crops they started growing commercial crops with use of chemical fertilizers to get higher returns, in long run which is leading to soil acidity and imbalance of nutrients and

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further drastic reduction in the production of crops and soils become unsuitable for crop production. However, it is important to attain maximum productivity without deteriorating soil quality is crucial approach to ensure sustainability in agriculture (Askari and Holden, 2014). The long–term consequences of these changes on soil properties are poorly understood and require collaborative interdisciplinary research. In this context, the present study was conducted to investigate the effect of different land use systems on physico-chemical and biological properties of soil in the southern transect of Bengaluru, Karnataka, India.

MATERIALS AND METHODS

Site description:

A common area for multidisciplinary research has been identified as Bengaluru's rural-urban interface. The Northern transect, which runs north from the city center, and the Southern transect, which runs south, are the two transects that make up Bengaluru District. The present study is confined to southern transect. It is polygon with a total area of 300 km^2, and the corner co-ordinates of southern transect are presented in Table 1. Districts that fall under administrative control in Bengaluru are represented by the red area. Yellow represents the outer ring road. The reference point (Vidhana Soudha) in the city center is indicated by the star mark, and the northern and southern research transects are shown by the blue contour (Fig. 1).

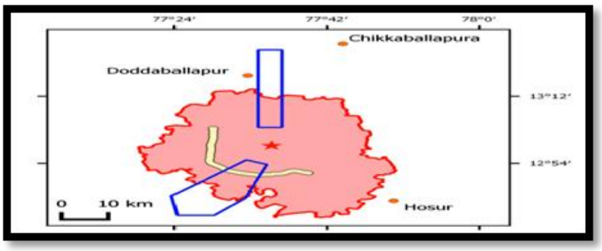

Fig. 1: Rural–urban interface of Bengaluru

Table 1: Corner coordinates of the Southern-transect

Southern- transect	
77.54041° E	12.91496° N
77.58161° E	12.89523° N
77.53850° E	12.74446° N
77.47762° E	12.66770° N
77.40577° E	12.66762° N
77.39460° E	12.75478° N

Land use systems:

The initial assessment revealed four main land-use systems, including agriculture, horticulture, mulberry and plantation crops. The conventional agricultural crops (L_1) were finger millet, maize, millets, pulses such field beans and grams. Horticulture crops (L_2) identified were chilli, cabbage, cauliflower, tomato, brinjal, capsicum, *etc.*, whereas mulberry (L_3) is the major commercial crop next to these groups in the transect and wider-spaced long-duration plantation crops (L_4) such as coconut, banana, mango, sapota, *etc*. were poorly maintained and did not have organic manures supplied since organic manures were not available, and they are close to the city. No intercrop was grown in most of the plantation land use.

Soil sampling and analysis:

A total of 50 soil samples were taken at a depth of 0 to 15 cm from each major land-use system in the study area. The samples were then air-dried in shade, ground with a wooden mallet and passed through a 2 mm sieve before being examined for different physical, chemical and biological properties of soil. Particle size analysis was done by international pipette method as described by Jackson, 1973, soil pH was determined in 1:2.5 soil: water suspension using pH meter and EC was measured using conductivity bridge (Jackson, 1973), organic carbon as determined by wet oxidation method as described by Walkley and Black (1934). Available nitrogen was estimated by kjeldhal digestion and distillation method by Subbiah and Asija, 1956. Where as available phosphorus, potassium and exchangeable Ca and Mg as outlined by Jackson, 1973. The available sulphur was measured by turbidometry method (Black, 1965). DTPA extractable micronutrients (Fe, Mn, Zn and Cu) by Lindsay and Norvell, 1978 and boron in soil was extracted by forming stable complex with azomethine-H reagent (Page *et al.*, 1982). Heavy metals (Pb, Cd, Cr and Ni) were determined by atomic absorption spectrophotometry (Lindsay and Norvell, 1978). The dehydrogenase activity in the soil samples was determined as described by Casida *et al.* (1964).

The one-way analysis of variance (ANOVA) was used to test differences in soil physical and chemical properties across land use types. Differences in mean at $p < 0.05$ were considered to be statistically significant at 5 per cent level of significance (Gomez and Gomez, 1984). Strength of different soil properties were determined by the Pearson's correlation coefficient (r).

RESULT AND DISCUSSION

Soil physical attributes

Particle-size distribution is commonly used as important indicators to evaluate agricultural management practices (Yang *et al.* 2012) as well as for estimating various related soil properties (Hillel 1980). The soil textural fractions of sand and clay significantly varied among the land use types while silt content was found non-significant. In all the land use system sand fraction is dominant it and varies from 37.15 to 68.95. In addition, per cent clay content varies from 14.65 to 45.33 under different land use systems of southern transect of Bengaluru (Table 3). The highest mean value of sand was recorded in the agriculture land-use system (55.93 %). Whereas, the clay content was found highest in plantation land use (30.11%) and the lowest was found in agriculture land use (27.42%). The lowest clay content under agriculture land use might be associated with the routine agriculture practices such as ploughing, harrowing, threshing and intercultural operations leading to mechanical disturbance to the upper soil thereby clay deposits in the lower layers. Chemeda *et al.* (2017) stated that the clay content of cultivated land was increased from the surface to the subsurface soil layer due to the long period of cultivation. Generally, the variation of soil texture among land use systems could be attributed to different utilization and management practices of land use types (Abbasi *et al.* 2007).

Table 2: Relevant descriptive statistics of different soil attributes in southern transect

	N	Minimum	Maximum	Mean	S.D	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	S.E	Statistic	S.E
Sand	200	37.15	68.95	54.39	6.06	-0.20	0.17	-0.32	0.34
Silt	200	8.97	34	15.7	4.08	0.73	0.17	0.94	0.34
Clay	200	14.65	45.33	29.33	6.07	0.02	0.17	-0.60	0.34
pH	200	4.23	8.56	6.44	1.28	-0.02	0.17	-1.27	0.34
EC	200	0.010	2.96	0.62	0.65	1.80	0.17	2.81	0.34
OC	200	0.19	1.23	0.64	0.28	0.46	0.17	-1.09	0.34
N	200	166.50	578.23	304.05	84.97	0.37	0.17	-0.58	0.34
P_2O_5	200	10.56	49.56	27.21	9.73	0.40	0.17	-0.77	0.34
K_2O	200	107.51	423.56	222.91	66.49	0.32	0.17	-0.46	0.34
Ca	200	2.56	18.96	9.25	2.93	0.39	0.17	-0.18	0.34
Mg	200	1.25	10.25	7.03	2.05	-0.51	0.17	-0.30	0.34
S	200	4.25	29.47	18.42	6.40	-0.38	0.17	-0.93	0.34
Fe	200	3.15	24.98	11.54	4.40	0.55	0.17	0.20	0.34
Mn	200	1.15	13.25	7.91	2.50	-0.25	0.17	-0.42	0.34
Zn	200	0.13	1.32	0.68	0.37	0.49	0.17	-1.17	0.34
B	200	0.14	1.63	0.74	0.29	0.52	0.17	0.63	0.34
Cd	200	0.00	0.21	0.04	0.04	1.53	0.17	3.40	0.34
Cr	200	0.00	0.21	0.04	0.03	1.80	0.17	5.75	0.34
Pb	200	0.00	0.35	0.03	0.05	4.37	0.17	24.20	0.34
Ni	200	0.00	0.33	0.04	0.04	5.14	0.17	33.84	0.34
DHA	200	3.33	29.65	13.48	7.21	0.51	0.17	-0.95	0.34

Soil pH, EC and OC

The soil pH varied significantly among different land use systems. It ranges from 4.2 3 to 8.56 under different land use systems. The highest and lowest mean values of soil pH were recorded in agriculture (7.08) and plantation (5.99) land use systems. Intensive agriculture practices such as heavy tillage practices and excess application of nitrogenous fertilizer had led to soil acidity in horticulture and mulberry land use systems. Continuous cultivation practices, excessive precipitation and application of inorganic fertilizers could be some of the factors which are responsible for the variation in pH (Chemeda *et al.* 2017). The greater pH values in the croplands (6.4-6.7) could be attributed to the release of bases and their deposition over a long period (Mandal *et al.* 2013). The EC content varied significantly and found higher in agriculture land use (0.88 dS m^{-1}) and the lowest was recorded in plantation land use (0.39 dS m^{-1}). The high EC content in agriculture land use might be attributed to the continuous application of fertilizers and manure to crops might have led to the accumulation of salts in the soils. Similar results were reported by Sumita *et al.* (2019). The lowest EC content in plantation land use might be attributed to uptake of bases by tree biomass, the acidic nature of litter after its decomposition. These results are in conformity with Tufa *et al.* (2019). Among the different land-use systems agriculture land use (0.75 %) recorded higher OC content followed by horticulture (0.65 %) and mulberry (0.61%) whereas the lowest was recorded in plantation land use (0.56%). The highest OC content in agricultural land use might be due to the regular application of manures before the sowing of crops and less organic carbon in case of plantation land use might be due to unavailability of organic manure to farmers as these are near to city.

Table 3: Soil physico-chemical properties of different land-use systems in southern transect of Bengaluru

Land use systems	Sand (%)	Silt (%)	Clay (%)	pH	EC (dSm^{-1})	OC (%)
L_1: Agriculture	55.93	16.02	27.42	7.08	0.88	0.75
L_2: Horticulture	55.38	15.33	28.80	6.47	0.66	0.65
L_3: Mulberry	53.67	15.88	29.99	6.24	0.55	0.61
L_4: Plantation	52.61	15.91	31.11	5.99	0.39	0.56
SE.m.±	0.84	0.58	0.83	0.16	0.09	0.04
CD (p = 0.05)	2.35	1.62	2.32	4.6	0.25	0.11

Available N, P_2O_5 and K_2O

The available nitrogen contents in different land types ranged from 166.50 to 304.05 kg ha^{-1} Among the different land use, agriculture land use (333.45 kg ha^{-1}) recorded significantly higher available nitrogen and lowest was recorded in plantation land use (281.29 kg ha^{-1}). Similarly, P_2O_5 and K_2O (30.87 and 250.82 kg ha^{-1}) recorded significantly higher in agriculture land use and lowest was recorded in plantation land use (3.70 and 198.17 kg ha^{-1}). The variations of available N, P_2O_5 and K_2O content among different land use types followed similar trend as that of soil organic carbon content. Excess application of fertilisers to get higher returns causes soil acidity which intern affects the availability of nutrients in horticulture and mulberry land use.

Table 4: Soil available major nutrients of different land-use systems in southern transect of Bengaluru

Land use systems	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Ca (c mol (p^+) kg^{-1})	Mg (c mol (p^+) kg^{-1})	S (mg kg^{-1})
L_1: Agriculture	333.45	30.87	250.82	10.71	7.96	19.56
L_2: Horticulture	309.77	28.97	229.69	9.59	7.63	18.09
L_3: Mulberry	291.68	25.28	212.94	8.89	6.74	17.83
L_4: Plantation	281.29	23.70	198.17	7.82	5.80	18.21
SE.m.±	11.57	1.31	8.49	0.39	0.27	0.90
CD (p= 0.05)	32.28	3.66	23.68	1.07	0.74	2.52

The lower available nutrients N, P_2O_5 and K_2O in plantation might be due to soil erosion, improper fertiliser application, and higher biomass of plantation crops had led to more uptake from soil and lowered nutrient status in plantation land use. Alemayehu and Sheleme reported that soil available P was significantly affected by land use types. The higher available P_2O_5 and K_2O in agriculture land probably due to judicious and regular application of P and K containing fertilizers and build-up nutrients was observed (Rajwinder and Bhat 2017). These results are confirm with findings of Geetha *et al.*, 2021 reported that significantly higher soil available K_2O was observed under agricultural crops. Van der Eijk *et al.* reported that the high content of P under cultivated land (maize) than of grass land soils could be due to the continuous application of phosphorus fertilizer applications. Indiscriminate use of inorganic fertilizers leads to nutrient imbalance in soil causing ill effect on soil health and micro flora (Choudhary *et al.* 2015).

Exchangeable Ca, Mg and available sulphur

Among the different land use systems, agricultural land-use was recorded higher Ca (10.71 c mol (p^+) kg^{-1}) and Mg (7.96 c mol (p^+) kg^{-1}). The lower Ca (7.82 c mol (p^+) kg^{-1}) and Mg (5.80 c mol (p^+) kg^{-1}) were recorded in plantation land use. The content of available sulphur was found non-significant and varies from 4.25 to 29.47 mg kg^{-1}. The low content of secondary nutrients in plantation might be associated to the poor soil management practises such no application of FYM and secondary nutrients in the form fertilizers and one more reason might be there was no intercrop in between plantation crops causing removal of soil along with nutrients through water erosion. The presence of such significant variation on exchangeable Ca and Mg could be attributed to different management practices and the variation in soil properties such as soil texture and OM (Mulugeta *et al.* 2019). Similarly, Ufot *et al.* (2016) reported that exchangeable Ca and Mg affected by different land use types.

Soil micronutrients (Fe, Mn, Cu, Zn and B)

Generally, the micronutrient contents of the soil depend on other soil parameters such pH and OM (Peraza *et al.*, 2017). Plantation land use marked significantly higher Fe (12.99 ppm) and Mn (8.51 ppm) contents followed by mulberry (12.16 ppm and 8.23 ppm) and horticulture (11.20 ppm and 7.97 ppm), while the lowest was in agriculture land use system (9.83 ppm and 6.96 ppm). The concentration of Fe and Mn were in the toxic level in all land use systems, as the concentrations of Fe and Mn were greater than 12.99 ppm and 8.51 ppm compared to the critical level of 5 ppm. The higher content of Fe and Mn could be attributed to pH of the soil where iron and manganese becomes more available in acidic condition of soil (Alemayehu and Sheleme 2013). The Zn and B were found high in agriculture land use system (0.808 ppm and 0.859 ppm). This might be due to the input from agricultural activities such as livestock manure, boron containing fertilizers, and agrochemical sprays. These results are in accord with findings of Chemeda *et al.* 2017 stated that the highest contents of Zn (1.87 ppm) and Cu (3.03 ppm) were recorded under the cultivated land.

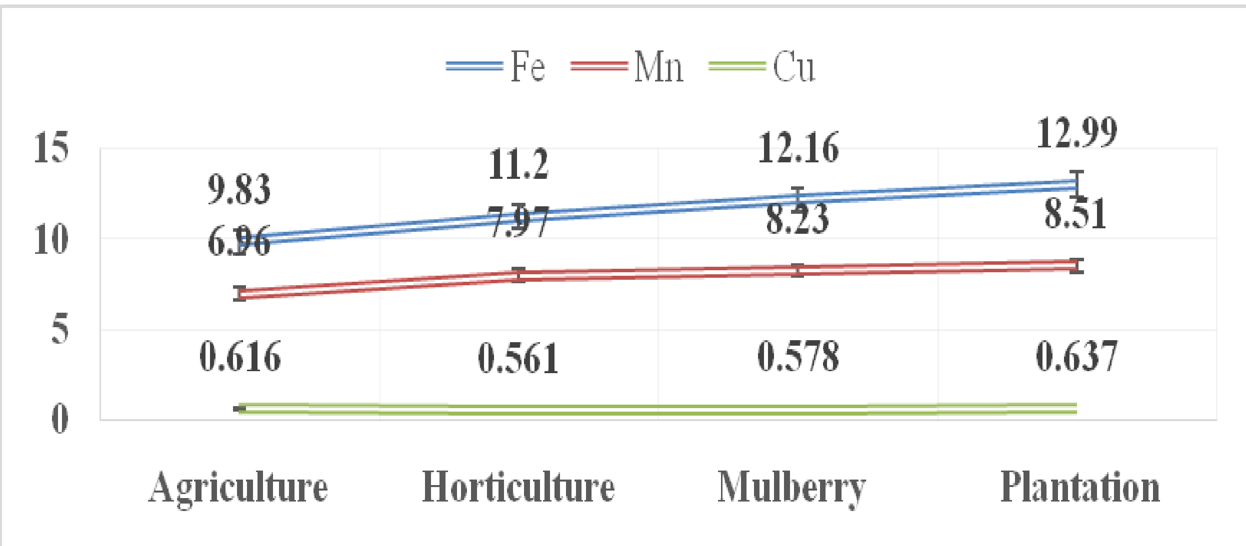

Fig 2: DTPA extractable Fe, Mn and Cu content (ppm) of different land use systems in southern transect of Bengaluru

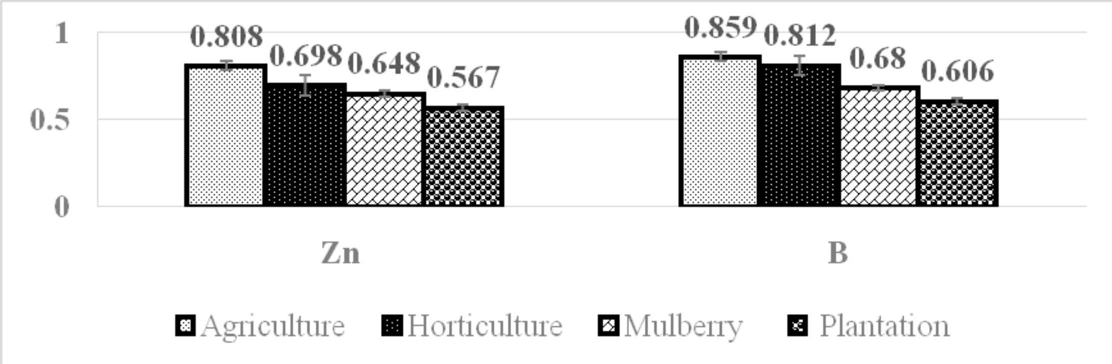

Fig 3: DTPA extractable Zn and B content (ppm) of different land use systems in southern transect of Bengaluru

Heavy metals (Cd, Cr, Pb and Ni)

Among the different land-use systems, heavy metals (Cr, Pb, and Ni) were found non-significant whereas Cd was found significantly different among the land-use system. The higher content Cd was recorded in horticulture land use (0.049 ppm) and this might be due to the continuous application of phosphate fertilizers contributed Cd to soils. Agricultural activities and especially application of manure, mineral fertilizers and pesticides into soils also significantly contribute to the trace metal status of agroecosystem (Kabata and Mukherje, 2007). Similarly, different researchers reported that agricultural soils are influenced by heavy metals derived from chemical fertilizers, pesticides and anthropogenic activities (Huang and Jin, 2008).

Table 5: Heavy metal content (ppm) of different land use systems in southern transect of Bengaluru

Land use systems	Cd	Cr	Pb	Ni
L_1: Agriculture	0.035	0.041	0.022	0.035
L_2: Horticulture	0.049	0.047	0.037	0.037
L_3: Mulberry	0.030	0.042	0.030	0.036
L_4: Plantation	0.029	0.041	0.019	0.038
SE.m.±	0.005	0.004	0.006	0.006
CD (p= 0.05)	0.197	0.176	0.216	0.216

Dehydrogenase

The dehydrogenase activity was found significantly different among land use. Among the different land-use systems, agriculture (15.83 µg TPF g^{-1} soil 24 h^{-1}) was recorded significantly higher dehydrogenase activity followed by horticulture (14.07 µg TPF g^{-1} soil 24 h^{-1}) and lower dehydrogenase activity was recorded in plantation land use (11.34 µg TPF g^{-1} soil 24 h^{-1}). The low dehydrogenase activity was associated with low organic input applications. The availability and amount of OC is the key factor affecting activity and structure of the microbial community (Pradeep *et al.* 2018).

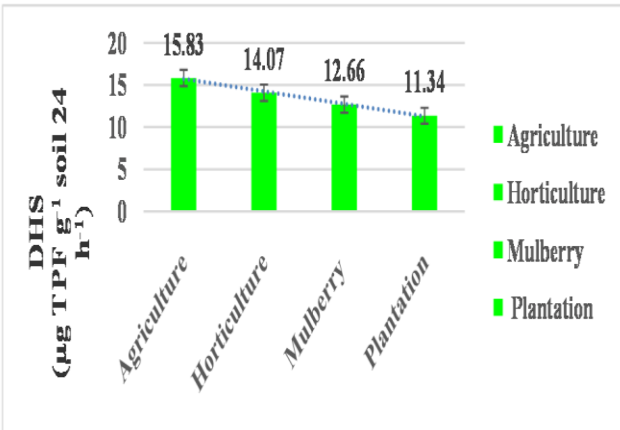

Fig 4: Dehydrogenase activity of different land use systems in southern transect of Bengaluru

Table 7: Correlation coefficients among the different soil physical, chemical and biological attributes

	Sand	Silt	Clay	pH	EC	OC	N	P_2O_5	K_2O	Ca	Mg	S	Fe	Mn	Cu	Zn	B	Cd	Cr	Pb	Ni	DHA
Sand	1.00																					
Silt	-0.34	1.00																				
Clay	-0.77	- 0.34**	1.00																			
pH	0.13	-0.18	-0.01	1.00																		
EC	0.03	0.05	-0.07	0.44**	1.00																	
OC	-0.01	0.00	0.00	0.09	-0.01	1.00																
N	0.03	-0.06	0.01	0.13	-0.01	0.93**	1.00															
P_2O_5	0.11	-0.02	-0.11	0.18*	0.07	0.20**	0.23**	1.00														
K_2O	0.03	0.01	-0.04	0.19**	0.09	0.51**	0.56**	0.19**	1.00													
Ca	0.06	-0.07	-0.01	0.46**	0.25**	0.05	0.04	0.10	0.15*	1.00												
Mg	0.12	-0.07	-0.08	0.33**	0.15*	0.03	0.01	0.07	0.12	0.87**	1.00											
S	-0.04	-0.08	0.10	0.00	-0.02	0.07	0.07	0.10	-0.02	0.13	0.06	1.00										
Fe	-0.14	0.17*	0.03	-0.79	-0.30	-0.10	-0.14	-0.16	-0.22	-0.39	-0.31	-0.01	1.00									
Mn	-0.20	0.11	0.12	-0.56	-0.18	-0.10	-0.11	-0.12	-0.21	-0.34	-0.30	-0.02	0.67**	1.00								
Cu	0.07	0.08	-0.11	0.05	-0.01	-0.01	-0.01	-0.05	0.03	-0.06	-0.02	-0.33	-0.01	-0.08	1.00							
Zn	0.06	-0.04	-0.04	0.14	0.07	0.23**	0.26**	-0.07	0.28**	-0.05	-0.02	0.01	-0.19	-0.09	0.01	1.00						
B	-0.01	-0.02	0.02	0.33**	0.14	0.19**	0.21**	0.16*	0.20**	0.18*	0.17*	-0.12	-0.27	-0.19	0.16*	0.21**	1.00					
Cd	0.05	0.08	-0.10	-0.03	.141*	0.01	0.01	-0.05	0.02	0.00	-0.02	0.01	-0.02	-0.03	0.00	0.13	-0.02	1.00				
Cr	-0.02	0.03	0.01	-0.04	0.04	0.02	0.01	0.02	-0.15	0.09	0.08	0.05	-0.02	-0.02	0.11	0.04	0.04	0.07	1.00			
Pb	0.02	0.13	-0.11	-0.06	-0.10	-0.02	-0.07	-0.11	-0.10	0.07	0.08	0.10	0.09	0.00	-0.02	-0.08	0.01	-0.02	0.10	1.00		
Ni	-0.02	0.04	-0.01	-0.20	-0.04	-0.03	-0.07	-0.10	0.07	-0.04	-0.01	-0.09	0.171*	0.10	-0.15	-0.13	-0.04	0.05	0.07	0.01	1.00	
DHA	0.03	0.00	-0.03	0.06	0.02	0.92**	0.88**	0.18*	0.49**	0.02	0.00	0.06	-0.07	-0.10	-0.01	0.26**	0.18**	-0.01	0.00	0.03	0.01	1.00

***. Correlation is significant at the 0.01 level (2-tailed)*
**. Correlation is significant at the 0.05 level (2-tailed)*

Correlation coefficient between the soil physico-chemical and biological properties

Correlation between the soil physico-chemical and biological properties of different land use systems in southern transact of Bengaluru are presented in Table 7. Correlation studies (*P*=0.01) indicated that organic carbon significantly and positively correlated with soil available nitrogen (0.93**), dehydrogenase activity (0.92**), available potassium (0.51**), zinc (0.23**), phosphorous (0.20**) and boron (0.19**). Similarly, pH was found to be correlated with electrical conductivity (0.44**), available potassium (0.19**), exchangeable calcium (0.46**) and magnesium (0.33**), and boron (0.33**).

It many concluded from the results that the variation in soil physico-chemical and biological properties may be attributed to frequent tillage practice, crop residue harvest, application of acid forming fertilizers and conversion of agriculture land use to the other land use types that causes poor nutrient availability in the soil. Continuous application of higher amount of fertilizer may pose deleterious effects on physical, chemical and biological properties of soil. Conservation agriculture, judicious use of chemical fertiliser, soil erosion control measures, organic residues incorporation, *etc*., should be promoted to improve soil health in different land use systems of southern transect of Bengaluru.

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