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Soil fertility status and nutrient index in surface and sub-surface soils of different land use systems in Gwalior Chambal division of Madhya Pradesh

Braj Kishor Rajput, SK Trivedi and SK Sharma and Shashi S Yadav

Abstract
Present study was carried out in Gwalior Chambal division of Madhya Pradesh state, India with the aim of fertility status evaluating of soils using nutrient index approach, mainly for primary nutrients (N, P & K) as well as sulphur. Soils of the studied areas were sandy loam to sandy clay loam in texture with normal calcium carbonate content. Electrical conductivity was normal (<1.0 dS m^{-1}) and pH of soils (7.32 to 8.32) was normal to moderately alkaline. Surface soils contained more organic carbon content as compared to sub surface soils and were low to medium in all the land use system except forest. Maximum surface soil samples of available nitrogen was low (80%), whereas more than half (> 50%) soil samples were in medium category in available phosphorus, potassium and sulphur. Nutrient index value for available N was found to be low (<1.67 range) and for available phosphorus, potassium and sulphur were medium (1.67 to 2.33).

Keywords: Fertility, primary nutrients, nutrient index, surface soils

Introduction
Fertility of the soil fertility has dynamic natural property and it can change only influence by natural and human induced factors. Soil organic matter (SOM) is an important factor which decides the management in fertility of forest soil. The forest soils differ in physico-chemical changes with time and space resulting in variation among microbial activities, processes of weathering, topography, climate, vegetation cover and also biotic or abiotic factors. Under different land use system, fertility of the soil fluctuates throughout the growing season in each year due to changes in the quantity and availability of mineral nutrients which is added through chemical fertilizers, organic manure, compost, and organic mulch and liming. Hence, evaluation of status of fertility of soils of an area or a region is very important aspect for sustainable agriculture. The physical and chemical parameters of soil which regulates biological activity of soil and exchange of ions between the solid, liquid and gaseous phases which influence nutrient cycling, decomposition of organic materials and plant growth. Organic matter content is one of the important factors for determination quality of soil and serves as sources of nutrients for improving physical and biological properties of soils in addition to productivity. Chemical environment of soil is dynamic and reactions that maintain solution of nutrient elements are indispensable for continuously plant growth. The nutrient availability and its transformation in soils depend on its pH, composition of clay minerals, keeping above facts the present study on nutrient status and nutrient index for primary nutrients (N, P & K) as well as available sulphur in Gwalior Chambal division of Madhya Pradesh was carried out.

Materials and Methods
Under present study one hundred twenty five sites of five different land use systerm (namely; Agriculture (Rice –Wheat), Horticulture (Vegetables fields), Agri–Horticulture (Guava-Blackgram/Greengram), Ravines (Fallow – mustard) and Forest (Tapowan-Forest area) of Gwalior-Chambal division were selected and each site surface (0.0 – 0.15 m depth) and sub-surface (0.15 – 0.30 m depth) soil samples were collected. The processed soil samples were analyzed for mechanical parameters (Sand, Silt & Clay) by Bouyoucos Hydrometer method (Bouyoucos, 1952) [1], pH and electrical conductivity in 1:2 soil water suspension by pH and conductivity metet, organic carbon content by Walkley and Black, (1934) [20], available nitrogen by Alkali permanganate method as per outleted by Subbiah and Asija, (1956) [18],

available phosphorus by spectrophotometer with ascorbic acid indicator used as per described by Olsean *et al.*, (1954) [12], available potassium estimates by Flame photometer using 1 N CH_3COONH_4 extrantent, available sulphur by $Cacl_2$ Extraction methods. The available nutrient categories in low, medium and high category and nutrient index were calculate as proposed by Ramamoorthy and Bajaj (1969) [15], which are discussed below:

N.I = {(1 x NL) + (2 X NM) + (3 XN H)}/ TNS

Where,
NL = Number of samples in low category;
NM = Number of samples in medium category;
NH = Number of samples in high category,
TNS = Total number of samples.

The nutrient index with respect to available N, P, K and S were used to evaluate the fertility status of soils in different land use systems in Gwalior Chambal division of Madhya Pradesh. The rating of nutrient index value was low (< 1.67), medium (1.67 to 2.33) and high (> 2.33).

Results and Discussion

The important mechanical and physico-chemical parameters of the soils are presented in Table 1. The soils of different land use system was in sandy clay loam in texture and sub-surface soils show more clay content as compared to surface soil. Maximum and minimum clay content were recorded in forest and ravines land use system in both the layers. Clay particles in subsurface horizons increased might be due to vertical movement from surface to subsurface by illuvation process. Movement and accumulation of soil particles which leading variation in soil properties (Moges and Holden, 2008) [10]. The soils were normal to alkaline with pH ranging between 7.32 to 8.24 and 7.44 to 8.36 with an average value of 7.81 and 7.93 in surface and sub-surface soils, respectively. It is revealed from result (Table 1) that sub-surface soils show higher pH as compared to surface soil in all the land use system. The reason may be attributed to leaching of bases with percolation water in deeper layer of soil and uptake by the crops and also decrease in organic matter accumulation with the depth. Besides, oxidation of ammonium to nitrate is more in surface soil may cause the relatively lower pH of surface soil. (Kumar *et al.*, 2017) [5]. Electrical conductivity was 0.45 and 0.52 dSm^{-1}, in surface and sub-surface soils, characteristic of normal soils. The organic carbon content ranging from 3.35 to 7.88 g kg^{-1} (mean 5.48 g kg^{-1}) and 3.07 to 6.55 g kg^{-1} (mean 4.67 g kg^{-1}) in surface and sub-surface soils, respectively. The status of organic carbon content in most of the soils was low to medium and it decreased with the increase in soil depth which might be attributed to more addition of organic materials like plant residues, organic manures and other organic materials in top soil than subsoil. Our results are in accordance with the observations of (Patangray *et al.* 2018) [13]. In case of land use system, maximum organic carbon content in both layer was recorded in forest whereas minimum in ravines areas. The high organic carbon content in forest land soil is due the luxuriant growth of grasses along with the seasonal decomposition of vegetative parts and roots and Surface soils show more organic carbon content as compared to sub-surface soils in all the land use system. These results are in same line to those of Gupta *et al.* *(*2003) [2]. Under present study, higher bulk density was noted in ravines area whereas lower with forest land use system. The decrease in bulk density in natural forest and agri-horticulture systems can be related to the effect of relatively high organic carbon content due to heavy litter fall and their subsequent decomposition in the soil layers. Karan *et al.,* (1991) [4] who reported higher values of bulk density in cultivated soil in comparison to grasslands or forest soils.

Available macro nutrient

Status of available macro nutrients (N, P & K) and available –S under surface and sub-surface soils in different land use system are presented in Table 2.

Available –N

Under studies land use system, available –N was observed in the range of 148.4 – 361.4 and 136.2 – 285.0 kg ha^{-1} with the average value of 214.0 and 194.2 kg ha^{-1} in surface and subsurface soils, respectively. It is clear from table-2, that surface soils contained more values of available N in all the land use system as compared to sub surface soils. The soils under forest land use system contained relatively higher content of available-N followed by Agri-horticulture field and minimum under ravines land use system in both the layers. This finds support from similar observation reported by Sharma *et al.* (2016) [16]. The lower nitrogen content in soil of ravines land use system may be attributed to the congenial atmosphere for leaching losses of nitrogen owing to the sandy texture and low application of nitrogen in mono cropping systems. On the other side, higher content in forest land might be due to availability of resource materials increases above the forest land that can be colonized, decomposed and mineralized by the microorganisms which is present in the soil and also retains moisture on the forest floor which may induce soil organic matter decomposition and nutrient mineralization in the soil (Maithani *et al*. 1998) [10]. Among total surface soil samples (125) of all land use system, 80.0% samples were found in low category (< 280 kg N ha^{-1}). In case of land use system, maximum soil samples (100%) was deficient in ravines followed by agriculture land use system (88%) whereas minimum (56%) was under forest land use system (Table-3). It might be ascribed that efficiency of applied inorganic N is very low due to lost through various mechanisms, like leaching, NH_3 volatilization, chemical and microbial fixation, run off, nitrification and succeeding de-nitrification. Similar results were also reported by Meena *et al.* (2006) [9] and Raghubanshi *et al*. (2011) [14].

Available-P

Status of available-P under different land use system are presented in Table 2. It is observed in the range of 6.32 to 32.65 and 5.18 to 21.16 kg ha^{-1} with the average value of 16.57 and 12.37 kg ha^{-1} in surface and subsurface soils, respectively. It is clear from result (Table-2) that surface soils contained higher content of available-P in all the land use system as compared to sub surface soils. The higher P content in surface soil may be due to the, higher amount of organic matter present, supplementation of the depleted P by external sources like fertilizers for crop cultivation. Due to more fixation of released P by clay minerals, oxides of iron and aluminum, sub-surface layers contained lower P than surface layer of soil (Kumar *et al*, 2017) [5].

In case of land use system, the soils under forest land contained relatively higher content of available –P in both the surface. Higher concentration of Phosphorous in forest areas soils may be attributed to rapid Phosphorous cycling in forests by decomposition and the mineralization of more Phosphorous-rich litter which help to maintain greater concentrations of Phosphorous in these soils, until uptake and accumulation in living biomass removes Phosphorous from this cycle (McGrath, *et al.* 2001) [8]. Among total surface soil samples (125) of all land use system, 56.0% samples were found to be medium category (10-20 kg p ha^{-1}). In case of land use system, maximum soil samples (92%) was low (<10 kg p ha^{-1}) in ravines whereas all of the samples of forest and vegetables field was found under medium and higher category of available-P (Table-3).

Available-K

The available-K content under studied land use systems was found in the range of 142.2 to 462.0 and 176.4 to 581.4 kg ha^{-1} with 248.2 and 292.0 kg ha^{-1} average value in surface and sub-surface soils, respectively. Surface soils contained less values of available –K in all the land use system as compared to sub surface soils (Table-2). Maximum and minimum content of available –K was noted under forest and ravines land use system in both the surface. The higher potassium in soils of natural forests may be because increase in organic matter in soils these formed clay-humus complex which become more active and providing more exchange sites for access to K Namgial *et al*. (2020) [11] and Kumari and Kumari (2014) [6]. Among total surface soil samples (125) of all land use system, 57.6% samples were falls in medium category (108-280 kg K ha^{-1}). In case of land use system, maximum soil samples (56%) was found in low (<108 kg K ha^{-1}) in ravines followed by agriculture (36%) land use system (Table-3).

Available-S

Under different land use system, available –S was observed in the range of 7.12 to 28.65 and 6.08 to 19.65 with the average value of 13.37 and 10.68 mg kg^{-1} in surface and subsurface soils, respectively. The soils under forest land use system contained relatively higher content of available-S followed by horticulture field and minimum under ravines in both the layers and surface soils contained more values of available S in all the land use system as compared to sub surface soils. In forest, addition of organic residues through leaf fall which increase organic matter content in soil and application of S-containing fertilizers in horticulture field's increases concentration of available S in the surface soil. These findings are in accordance with the observations of Hoque *et al*. (2020) [3]. Among total surface soil samples (125) of all land use system, 55.2% samples were found in medium category (10-20 mg S kg^{-1}). In case of land use system, maximum soil samples (84%) was found in low (<10 mg S kg^{-1}) in ravines followed by agriculture (76%) land use system (Table-3).

Nutrient index

Regarding soil nutrient index, the soils of different land use system of Gwalior Chambal division were found in category of medium for phosphorus, potassium and sulphur whereas nitrogen status is low. (Table 3). The value which is worked out from nutrient index formula for N, P, K, and S were 1.20, 1.78, 1.89 and 1.68, respectively, against the nutrient index values < 1.67 for low, 1.67-2.33 for medium and >2.33 value for high fertility status. Forest land show higher value of nutrient index as compared to other land use system. This is might to the fact that the top layer of forest soil is herbaceous and leaf litter that covers the soil surface and does not withhold plant nutrients for a long period in the standing biomass which may otherwise lead to an extended period of nutrient cycling. These results confirms studies conducted many workers (Srinivasan *et al.* 2017 and Sudhalakshmi *et al.* 2017) [17, 19].

Table 1: Status of mechanical and important physico-chemical parameters of soils in different land use system

S. No.	Land use system	Depth (cm)	Mechanical parameters		Physico-chemical parameters				
			Sand (%)	Silt + clay (%)	Soil pH	Electrical Conductivity (dSm^{-1})	Organic carbon (g kg^{-1})	Bulk density (Mg m^{-3})	Calcium Carbonate (%)
1	Agriculture (A) (Rice–Wheat)	0-15 cm	56.4	43.6	7.88	0.49	4.42	1.64	1.56
		15-30 cm	54.2	45.8	7.95	0.57	4.35	1.65	2.45
2	Horticulture (H) (Vegetables fields)	0-15 cm	51.2	48.2	7.76	0.38	4.85	1.58	1.32
		15-30 cm	48.7	51.3	7.86	0.44	4.06	1.62	1.65
3	Agri–Horticulture (AH) (Guava-Blackgram/ Greengram)	0-15 cm	52.4	47.6	7.84	0.34	6.88	1.41	1.45
		15-30 cm	47.9	52.1	7.95	0.38	5.32	1.44	1.75
4	Ravines (R) (Fallow – Mustard)	0-15 cm	62.8	37.2	8.24	0.78	3.35	1.72	1.62
		15-30 cm	57.6	42.4	8.36	0.94	3.07	1.74	2.74
5	Forest (F) (Tapowan Forest area)	0-15 cm	48.8	51.2	7.36	0.25	7.88	1.36	0.42
		15-30 cm	44.2	55.8	7.42	0.27	6.55	1.42	0.52
As a Whole		0-15 cm	54.4	45.6	7.82	0.45	5.48	1.54	1.27
		15-30 cm	50.5	49.5	7.91	0.52	4.67	1.57	1.82

Table 2: Status of available nutrients in different land use system

S. No.	Land use system	Depth (cm)	Available-N (Kg ha^{-1})		Available-P (Kg ha^{-1})		Available-K (Kg ha^{-1})		Available-S (Mg Kg^{-1})	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
1	Agriculture (A) (Rice –Wheat)	0-15 cm	165.2-296.2	189.7	9.65-17.32	14.22	166.2-352.6	215.6	8.26-19.65	12.38
		15-30 cm	151.2-214.6	165.2	6.98-14.28	11.08	214.8-388.6	275.0	7.15-16.02	9.45
2	Horticulture (H) (Vegetables fields)	0-15 cm	178.4-295.8	208.1	13.22-24.68	15.29	172.9-306.5	241.2	11.08-24.56	14.88
		15-30 cm	170.2-242.6	202.6	10.35-18.15	12.98	188.6-372.8	254.1	8.25-17.65	11.85
3	Agri–Horticulture (AH) (Guava-Blackgram/ Greengram)	0-15 cm	198.4-315.2	231.1	11.88-24.68	15.78	172.6-405.2	302.6	9.28-21.67	13.62
		15-30 cm	180.2-235.6	207.6	9.12-17.32	13.44	215.6-468.2	356.8	7.22-14.62	10.29
4	Ravines (R) (Fallow – Mustard)	0-15 cm	148.4-245.2	167.0	6.32-15.66	10.35	142.2-288.7	165.0	7.12-15.28	10.32
		15-30 cm	136.2-195.6	158.4	0.84-2.46	1.40	176.4-265.0	198.7	6.08-11.35	8.94
5	Forest (F) (Tapowan Forest area)	0-15 cm	232.4-361.4	274.1	18.36-32.65	27.22	282.1-462.0	316.8	13.25-28.65	15.66
		15-30 cm	218.3-285.0	237.3	15.30-21.16	16.68	322.4-581.4	375.4	11.05-19.65	12.87
As a Whole		0-15 cm	148.4-361.4	214.0	6.32-32.65	16.57	142.2-462.0	248.2	7.12-28.65	13.37
		15-30 cm	136.2-285.0	194.2	5.18-21.16	12.37	176.4-581.4	292.0	6.08-19.65	10.68

Table 3: Nutrient index of N, P & K and Sulphur in surface soils of different land use system.

S. No.	Land use system	Available Nitrogen				Available Phosphorus				Available Potassium				Available Sulphur			
		L	M	H	NI value	L	M	H	NI value	L	M	H	NI value	L	M	H	NI value
1	Agriculture (A) (25*)	22 (88.0)	03 (12.0)	00 (0.0)	1.12 (L)	18 (72.0)	07 (28.0)	0 (0.0)	1.28 (L)	09 (36.0)	13 (52.0)	03 (12.0)	1.76 (M)	19 (76.0)	06 (24.0)	00 (16.0)	1.24 (L)
2	Horticulture (H) (25)	18 (72.0)	07 (28.0)	00 (0.0)	1.28 (L)	00 (0.0)	21 (84.0)	04 (16.0)	2.16 (M)	06 (24.0)	16 (64.0)	03 (12.0)	1.88 (M)	06 (24.0)	17 (68.0)	02 (8.0)	1.84 (M)
3	Agri-Horti (AH) (25)	21 (84.0)	04 (16.0)	0 (0.0)	1.16 (L)	00 (36.0)	22 (88.0)	03 (12.0)	2.12 (M)	04 (16.0)	16 (64.0)	05 (20.0)	2.04 (M)	02 (8.0)	21 (84.0)	02 (8.0)	2.00 (M)
4	Ravines (R) (25)	25 (100.0)	0 (0.0)	0 (0.0)	1.00 (L)	23 (92.0)	02 (8.0)	00 (0.0)	1.08 (L)	14 (56.0)	10 (40.0)	01 (4.0)	1.48 (L)	21 (84.0)	04 (16.0)	00 (0.0)	1.16 (L)
5	Forest (F) (25)	14 (56.0)	11 (44.0)	0 (0.0)	1.44 (L)	00 (0.0)	18 (72.0)	07 (28.0)	2.28 (M)	00 (0.0)	17 (68.0)	08 (32.0)	2.32 (M)	00 (0.0)	21 (84.0)	04 (16.0)	2.16 (M)
Whole land use system		100 (80.0)	25 (20.0)	0 (0.0)	1.20 (L)	41 (32.8)	70 (56.0)	14 (11.2)	1.78 (M)	33 (26.4)	72 (57.6)	20 (16.0)	1.89 (M)	48 (38.4)	69 (55.2)	08 (6.4)	1.68 (M)

*Number of soil samples,
L-Low
M-Medium
H-High

Conclusion

From the present study it can be concluded that under varying land uses, distribution of soil properties as well as nutrient elements is affected by layers of different soil which find in various depths. Soil pH was lower but EC and organic matter content were higher in the surface soil compared to the sub-surface layers. Nutrient elements such as P, S and most of the K fractions were higher in upper layers compared to subsurface soil showing variation among the land uses. The forest soil naturally grown or non-cultivated soil by man was more enriched with nutrient elements followed by agri-horticulture land use system.

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