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Assessment of Chemical Properties of Soil under Different Land use Systems in a Mollisol

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A B S T R A C T

The present study was undertaken during *Kharif* 2017-18 to assess chemical properties of soil under different land use systems in a Mollisol. The study area was located at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar. The land use systems selected for study were rice–wheat–green gram, rice–pea(vegetable)-maize, rice-potato –okra, rice–berseem + oat + mustard(fodder)-maize + cowpea(fodder), maize–wheat–cowpea, sorghum(fodder)-yellow sarson-black gram, guava + lemon, poplar + turmeric, eucalyptus + turmeric and fallow(uncultivated land). Soil samples were taken from 0-20cm depth and analyzed for the various chemical properties. Soil pH (H_2O) varied from 7.38 to 7.49, electrical conductivity varied from 0.249 to 0.326 dSm^{-1} and CEC varied from 22.21 to 36.51 C mol(p+) kg^{-1} soil. Soil organic carbon content ranged from 0.54 to 1.52 percent. Available soil nitrogen content varied from 148.02 to 311.09 kg ha^{-1}, available soil phosphorus from 14.29 to 25.97 kg ha^{-1} and available soil potassium from 153.66 to 259.62 kg ha^{-1}. Available sulphur varied from 16.99 to 32.03 mg kg^{-1}. Among micronutrients, available zinc content in soil varied from 0.77 to 2.16 mg kg^{-1}, available copper content in soil from 3.83 to 5.89 mg kg^{-1}, available iron content in soil from 14.07 to 33.84 mg kg^{-1} and available Mn content in soil from 5.93 to 7.89 mg kg^{-1}. Results indicated that with respect to chemical properties of soil agroforestry based systems were found superior followed by field crops, horticultural crops and the fallow (uncultivated land).

Introduction

Chemical property of soil is an index of availability of nutrients and a function of various processes occurring in the soil. Chemical properties not only reflect the capacity of soil to provide congenial chemical and nutritional environment to plants but also supports biological and physical processes in soil.

Lal (2003) stated that soil is a significant long term reservoir of organic carbon and play a significant role in the global carbon cycle. But, cultivation exposes organic matter to a greater rate of decay and oxidation (Young and Young, 2001) resulting in low total nitrogen content (Havlin *et al.,* 2000). Cropping systems can affect a range of soil properties depending on the specific crop rotation, nutrient amendments, and tillage practices employed (Masto *et al.,* 2007). Over the time, this can result in soil quality degradation, improvement, or being maintained (Jokela *et al.,* 2009).

A better understanding of the impact of continuous crop rotations on chemical properties of soil is essential for evaluation of soil quality and thereby enhancing cropping system sustainability (Aparicio and Costa, 2007).

Present study was undertaken to assess the chemical properties of soil under different land use systems in a Mollisol.

Materials and Methods

The study area was located at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar. Five composite soil samples (0-20 cm depth) representing the whole area were collected randomly from different land use systems comprising of field crops, horticultural crops, agroforestry crops and fallow (uncultivated land) of the same block during *kharif*, 2017-18. Each composite soil sample was processed and used for the analysis of chemical properties.

Soil pH and EC were analysed by soil water suspension (1:2) (Jackson, 1967). Soil Organic carbon by Walkley and Black (1934) method.

CEC was analysed by Bache (1976) method. Available nitrogen content in soil was analysed by Subbiah and Asija (1956) method, available phosphorus in soil by Olsen *et al.,* (1954), available potassium in soil by Black (1965), available sulphur content by Williams and Steinbergs (1959) and available micronutrients was analysed by Lindsay and Norvell (1978) method.

The data were analysed statistically by using complete randomized design (C.R.D). The data collected on different soil properties were analysed applying ANOVA technique (Pansa and Sukhatme, 1985). The overall difference was tested by F test of significance at 5% level of probability. In case of significant F test, C.D. at 5% was calculated for comparing treatment means.

Results and Discussion

Soil pH

The pH (H_2O) of a soil indicates the degree of availability of plant nutrients and lime requirement of the soil. A number of soil fertility characters can be concluded from the soil pH (Landon, 1991). The data pertaining to the soil pH significantly differed under different land use systems and varied from 7.38 to 7.49 (Table 1). Lowest soil pH was recorded under eucalyptus + turmeric system which was significantly lower than the soil pH noted under all other systems except poplar + turmeric and rice-potato okra land use system. Soil pH noted under maize–wheat–cowpea and fallow (uncultivated) land was significantly lower than that of guava + lemon system.

Lowest soil pH was seen under agroforestry system i.e. eucalyptus + turmeric followed by poplar + turmeric system which might be due to high organic carbon content. The results are similar to the findings of Kumar (2015). The decomposition of organic matter released organic acids which lowered down the soil pH. Highest soil pH was seen under guava + lemon system. Similar results were also obtained by Ekka *et al.,* (2017) in case of guava based system.

Since the change in the pH are mainly because of the parent material and climate under which the soil formation takes place therefore very little changes in soil pH are observed within adjacent area or area of a few hectares. In this study all the sampling sites were adjacent to each other which might have resulted in the least variation in pH. Similar observations were also reported by Cox *et al.,* (2003) and Shukla *et al.,* (2004).

pH (KCl) significantly varied under different land use systems and ranged from 5.68 to 6.55. Lowest pH (KCl) and highest pH (KCl) was noted under eucalyptus + turmeric and fallow (uncultivated) land use system respectively. pH (KCl) recorded under eucalyptus + turmeric system was significantly lower than the pH noted under poplar + turmeric, rice-potato –okra, rice–wheat–green gram, rice–berseem + oat + mustard (fodder) - maize + cowpea(fodder), sorghum (fodder) - yellow sarson-black gram, rice–pea (vegetable) - maize, maize–wheat–cowpea, guava + lemon and fallow (uncultivated) land use system. pH (KCl) recorded under poplar + turmeric and rice-potato –okra system was significantly lower than that under rice–wheat–green gram, rice–berseem + oat + mustard (fodder) - maize + cowpea (fodder), sorghum (fodder) - yellow sarson-black gram, rice–pea (vegetable) - maize, maize–wheat–cowpea, guava + lemon and fallow(uncultivated) land use system. pH (KCl) under maize–wheat–cowpea system was significantly lower than that under fallow (uncultivated) land use system. In the present study, pH (KCl) was slightly lower than pH (H_2O). Similar observations were made by Ramzan (2013).

Delta pH varied significantly under different land use systems and it ranged from 0.92 (under fallow) to 1.70 (under eucalyptus + turmeric) (Table 1). Delta pH recorded under fallow land use system was significantly lower than the delta pH noted under all other systems except guava + lemon system. Delta pH noted under guava + lemon system was significantly lower than the delta pH noted under sorghum(fodder)-yellow sarson-black gram, rice–berseem + oat + mustard(fodder)-maize + cowpea (fodder), rice–wheat–green gram, rice-potato–okra, poplar + turmeric and eucalyptus + turmeric land use system.

Delta pH noted under rice-potato –okra system was significantly lower than that under eucalyptus + turmeric system.

Since the value of pH (H_2O) is greater than pH (KCl), delta pH values remained positive which is an indication of presence of negatively charged clay surface. Gurmessa (2002) also reported that when pH (H_2O) is higher than pH (KCl), the soil is dominated with layer of silicate minerals and oxides of iron and aluminum. Soil pH (KCl) indicates the potential acidity and presence of weatherable minerals when the difference of soil pH (H_2O) and pH (KCl) is greater than unity (Buol *et al.,* 2003).

Electrical conductivity

Electrical conductivity of soil significantly differed under different land use systems. It ranged from 0.249 to 0.326 dSm^{-1} (Table 1). Lowest value of electrical conductivity was recorded under fallow (uncultivated) land use system which was significantly lower than that noted under rice–berseem + oat + mustard (fodder)-maize +cowpea (fodder), rice-potato -okra, sorghum (fodder)-yellow sarson-black gram, rice–pea (vegetable)-maize, maize–wheat–cowpea, rice–wheat–green gram, eucalyptus + turmeric and poplar + turmeric land use system. Electrical conductivity recorded under rice-potato-okra, sorghum (fodder)-yellow sarson-black gram and rice–pea (vegetable)-maize system was significantly lower than that under maize–

wheat–cowpea, rice–wheat–green gram, eucalyptus + turmeric and poplar + turmeric land use system. Higher electrical conductivity under agroforestry system i.e. poplar + turmeric followed by eucalyptus + turmeric system was due to high organic carbon content. This might be due to the decomposition of organic matter (Larson and Pierce, 2002 and Nayak *et al.,* 2017). There was a significant increase in EC values under cultivated soils over uncultivated fallow land.

This might be due to irrigation, fertilizers and accumulation of salts in the root zone because of movement of soil solution under the influence of transpiration pull from sub surface of soil by dense crops and leaving the salts in the root zone (Tiwari *et al.,* 1995).

Cation exchange capacity

Cation exchange capacity of soil significantly differed under different land use systems and varied from 22.21 to 36.51 Cmol(p+) kg^{-1} soil (Table 1). Highest value of CEC was recorded under eucalyptus + turmeric system which was significantly higher than that under all other land use systems. CEC of soil noted under poplar + turmeric system was significantly higher than it was noted under rice-potato-okra, rice–berseem + oat + mustard(fodder)-maize + cowpea(fodder), rice–wheat–green gram, sorghum (fodder)-yellow sarson-black gram, rice–pea (vegetable)-maize, maize–wheat–cowpea, guava + lemon and fallow(uncultivated) land use system. CEC registered under guava + lemon system was significantly higher than that noted under fallow (uncultivated) land use system.

The higher CEC under agroforestry system i.e. eucalyptus + turmeric followed by poplar + turmeric was observed which might be due to high organic matter and clay content. Similar findings were also reported by Swaranam *et al.,* (2004).

Soil organic carbon

Organic carbon content significantly differed under different land use systems and varied from 0.54% to 1.52% (Table 2). Soil organic carbon content was recorded highest under eucalyptus + turmeric system which was significantly higher than the soil organic carbon content recorded under all other land use systems. Soil organic carbon content noted under poplar + turmeric system was significantly higher than that under rice-potato-okra, rice–berseem + oat + mustard (fodder)-maize + cowpea (fodder), rice–wheat–green gram, sorghum (fodder)-yellow sarson-black gram, rice–pea (vegetable)-maize, maize–wheat–cowpea, guava + lemon and fallow (uncultivated) land use system. Soil organic carbon noted under guava + lemon system was significantly higher than it was under fallow (uncultivated) land use system.

Higher soil organic carbon was reported under agroforestry based system i.e. eucalyptus + turmeric followed by poplar + turmeric. While, among the field crops, organic carbon followed the order: Rice-potato-okra > rice–berseem + oat + mustard (fodder)-maize + cowpea (fodder) > rice–wheat–green gram > sorghum(fodder)-yellow sarson-black gram in the present study. The superiority of agroforestry based systems (i.e. eucalyptus + turmeric followed by poplar + turmeric) over other land use systems might be due to dense canopy which lead to more nutrient accretion in the soil by minimizing the loss through soil erosion and leaching. Besides, enhanced litter production and congenial temperature for microbes. While among field crops based systems, rice-potato-okra was found better as compared to other field crops based systems might be due to higher soil organic carbon content. Least soil organic carbon content under fallow land might be due to poor vegetative cover and frequent cutting of the grasses and weeds from the soil surface. Comparatively higher organic carbon content in the forest based cropping system might be due to litter fall of the trees on the soil surface as reported by Singh *et al.*, (2006) and Patil and Prasad (2004).

The lowest organic carbon was observed in the maize based cropping system among the cereals which might be due to more exhaustive cropping system (Yadda, 2007). Significant increase in the soil organic carbon content under cultivated soils over the uncultivated soils was observed. This might be attributed to the addition of crop residues and organic manures in the cultivated soils (Tiwari *et al.*, 1995).

Available soil nitrogen

Available nitrogen content was significantly affected by different land use systems and ranged from 148.02 to 311.09 kg ha^{-1} at 0-20 cm depth (Table 2). Soil available nitrogen content was recorded highest under eucalyptus + turmeric system which was significantly higher than the available soil nitrogen reported under all other land use systems.

Table.1 pH H_2O, pH KCl, delta pH, EC, and CEC of soil under different land use systems

Land use systems	pH H_2O	pH KCl	delta pH	EC (dsm^{-1})	CEC (cmol (p^+) kg^{-1} soil)
Rice – wheat – green gram	7.42	5.99	1.43	0.312	30.90
Rice – pea (vegetable) –maize	7.44	6.32	1.12	0.292	29.08
Rice – potato – okra	7.41	5.87	1.54	0.283	33.37
Rice – berseem + oat + mustard (fodder) –maize+cowpea (fodder)	7.43	6.16	1.27	0.260	32.68
Maize – wheat – cowpea	7.45	6.40	1.05	0.307	28.02
Sorghum (fodder) – yellow sarson – black gram	7.44	6.23	1.21	0.290	30.53
Guava + lemon	7.49	6.46	1.02	0.258	26.29
Poplar + turmeric	7.40	5.79	1.61	0.326	35.63
Eucalyptus + turmeric	7.38	5.68	1.70	0.316	36.51
Fallow (uncultivated land)	7.47	6.55	0.92	0.249	22.21
SEm±	0.012	0.035	0.038	0.003	0.25
CD at 5%	0.035	0.101	0.107	0.011	0.72

Table.2 Soil organic carbon, available nitrogen, available phosphorus, available potassium, available sulphur, and micronutrients content in soil under different land use systems at 0 – 20 cm depth

Land use systems	Soil organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{1})	Available S (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})
Rice – wheat – green gram	1.13	248.37	24.51	217.28	26.05	1.85	4.53	23.16	7.12
Rice – pea (vegetable) – maize	1.04	220.77	21.13	210.11	21.09	1.71	4.34	21.22	6.67
Rice – potato – okra	1.27	283.49	24.97	229.82	28.51	1.94	5.10	27.02	7.17
Rice – berseem + oat + mustard (fodder) – maize+cowpea (fodder)	1.20	265.93	24.28	228.93	27.97	1.98	4.71	27.63	7.52
Maize – wheat – cowpea	1.01	213.25	21.75	196.90	20.82	1.49	4.92	18.11	6.36
Sorghum (fodder) – yellow sarson – black gram	1.13	238.34	21.52	220.64	24.26	1.65	4.75	20.15	6.90
Guava + lemon	0.80	205.72	18.06	186.82	20.59	1.31	4.14	17.15	6.11
Poplar + turmeric	1.40	298.55	25.67	239.23	30.66	2.07	5.67	30.51	7.71
Eucalyptus + turmeric	1.52	311.09	25.97	259.62	32.03	2.16	5.89	33.84	7.89
Fallow (uncultivated land)	0.54	148.02	14.29	153.66	16.99	0.77	3.83	14.07	5.93
SEm±	0.01	3.50	0.44	1.64	0.16	0.015	0.025	0.43	0.042
CD at 5%	0.04	10.01	1.25	4.69	0.46	0.045	0.071	1.24	0.12

Available soil nitrogen reported under poplar + turmeric system was significantly higher than that under rice-potato -okra, rice–berseem + oat + mustard (fodder)-maize + cowpea(fodder), rice–wheat–green gram, sorghum(fodder)-yellow sarson-black gram, rice–pea (vegetable)-maize, maize–wheat–cowpea, guava + lemon and fallow (uncultivated) land use system. Available soil nitrogen noted under maize–wheat–cowpea and guava + lemon system was significantly higher that under fallow (uncultivated) land use system. Higher availability of soil nitrogen under eucalyptus + turmeric system poplar + turmeric system might be due to high water holding capacity, porosity and organic carbon which helped in the mineralization of soil nitrogen leading to buildup of higher available nitrogen. Kumar (2015) reported that organic carbon is considered as an index of available nitrogen content of soils. Tisdale *et al.,* (1995) also reported that total N content of a soil is directly associated with organic carbon content. Srivastava *et al.,* (2015) reported relatively lower value of available soil nitrogen in fruit based cropping system as fruits are nutrient exhaustive and highly effective in nutrient mining from the soil.

Available soil phosphorus

The available phosphorus content in soil varied significantly under different land use systems and varied from 14.29 to 25.97 kg ha^{-1} (Table 2). The highest value of available soil phosphorus was recorded under eucalyptus + turmeric followed by poplar + turmeric and rice-potato-okra system. Available soil phosphorus under eucalyptus + turmeric and poplar + turmeric system was significantly more than noted under rice–wheat–green gram, rice–berseem + oat + mustard (fodder)-maize + cowpea (fodder), maize–wheat–cowpea, sorghum (fodder)-yellow sarson-black gram, rice–pea (vegetable)-maize, guava + lemon and fallow(uncultivated) land use system. Available soil phosphorus noted under guava + lemon system was found significantly higher than that under fallow (uncultivated) land use system. Yadda *et al.,* (2007) observed that with increase in the organic carbon content of the soil, the available phosphorus increases because of its fast mineralization in agroforestry systems. The phosphorus content under cultivated land use systems was significantly higher over fallow (uncultivated) land use system. This might be because of phosphate fertilization and accumulation of phosphorus. Soils under field crops land use systems with pulse cropping showed relatively lower value of available phosphorus than that under other land use systems.

This might be due to the fact that legumes utilize more phosphorus thereby depleting the phosphorus content in the soils (Tiwari *et al.,* 1995).

Available soil potassium

Available potassium content in soil differed significantly under different land use systems and varied from 153.66 to 259.62 kg ha^{-1} (Table 2). The highest value of available soil potassium was recorded under eucalyptus + turmeric system which was significantly higher than the values reported under all other land use systems. Available soil potassium noted under poplar + turmeric system was significantly higher than the available soil potassium reported under rice-potato-okra, rice–berseem + oat + mustard (fodder)-maize + cowpea (fodder), sorghum (fodder)-yellow sarson-black gram, rice–wheat–green gram, rice–pea (vegetable)-maize, maize–wheat–cowpea, guava + lemon and fallow(uncultivated) land use system. Available soil potassium reported under guava + lemon system was significantly higher than that under fallow (uncultivated) land use system.

Lower value of available potassium under field crop based land use systems than the agroforestry based systems might be due to depletion of potassium either because of vegetation removal or leaching loss. Kumar (2005) and Khongjee (2012) was also of the similar opinion. Results were confirmatory with the findings of Srivastava *et al.,* (2015).

Available soil sulphur

Available sulphur content in soil differed significantly under different land use systems and varied from 16.99 to 32.03 mg kg^{-1} (Table 2). The highest value of available soil sulphur was recorded under eucalyptus + turmeric system which was significantly higher than the value recorded under all other land use systems. Available soil sulphur under poplar + turmeric was significantly higher than the available soil sulphur reported under rice-potato -okra, rice–berseem + oat + mustard(fodder)-maize + cowpea(fodder), rice–wheat–green gram, sorghum(fodder)-yellow sarson-black gram, rice–pea(vegetable)-maize, maize–wheat–cowpea, guava + lemon and fallow (uncultivated) land use systems. Available soil sulphur observed under maize–wheat–cowpea and guava + lemon system was significantly higher than that under fallow (uncultivated) land use system.

Sharma *et al.,* (2013) observed lower sulphur content under cereal based system which may be due to more exhaustive nature of the cropping system. Higher sulphur content under agroforestry based system might be due to high soil organic carbon content because of recycling which adds to the soil sulphur reserve (Gangola, 2012).

Available soil Zn

Zinc content in soil differed significantly under different land use systems and varied from 0.77 to 2.16 mg kg^{-1} (Table 2). Highest value of zinc was recorded under eucalyptus + turmeric system which was significantly higher than the available Zn noted under all other land use systems. Available Zn in soil under poplar + turmeric system was significantly higher than under rice–berseem + oat + mustard (fodder)-maize + cowpea(fodder), rice-potato-okra, rice–wheat–green gram, rice–pea (vegetable) -maize, sorghum (fodder)-yellow sarson-black gram, maize–wheat–cowpea, guava + lemon and fallow (uncultivated) land use system. Available Zn in soil found under guava + lemon system was significantly higher than that under fallow (uncultivated) land use system. Highest zinc content under agroforestry based system (i.e. eucalyptus + turmeric and poplar + turmeric) might be due to low pH and high CEC of the soil. Similar results were also observed by Singh *et al.,* (2006) and Sharma *et al.,* (2013).

Available soil Cu

Available copper content of soil differed significantly under different land use systems and varied from 3.83 to 5.89 mg kg^{-1} (Table 2). Highest value of available copper in soil was recorded under eucalyptus + turmeric system which was significantly higher than the value of available copper noted under all other land use systems. Available Cu in soil noted under poplar + turmeric system was significantly higher than that under rice-potato -okra, maize–wheat–cowpea, sorghum (fodder) -yellow sarson-black gram, rice–berseem + oat + mustard(fodder)-maize + cowpea(fodder), rice–wheat–green gram, rice–pea(vegetable)-maize, guava + lemon and fallow(uncultivated) land use system. Available Cu in soil recorded under guava + lemon system was significantly higher than that under fallow (uncultivated) land use system.

Available soil Fe

Available iron content in soil significantly varied under different land use systems and ranged from 14.07to 33.84 mg kg^{-1} (Table 2). Highest value of available iron was recorded under eucalyptus + turmeric system which was significantly higher than the value noted under all other land use systems. Available Fe in soil noted under poplar + turmeric system was significantly higher than that under rice–berseem + oat + mustard (fodder)-maize + cowpea (fodder), rice-potato-okra, rice–

wheat–green gram, rice–pea(vegetable)-maize, sorghum (fodder)-yellow sarson-black gram, maize–wheat–cowpea, guava + lemon and fallow(uncultivated) land use system. Available Fe in soil registered under maize–wheat–cowpea and guava + lemon system was significantly higher than that under fallow (uncultivated) land use system.

Higher iron availability under agroforestry based system (i.e. eucalyptus + turmeric and poplar + turmeric) might be due to higher soil organic carbon content under these systems. Sarkar *et al.*, (2001) was also of the similar opinion.

Available soil Mn

Available Mn content in soil varied significantly under different land use systems and varied from 5.93to 7.89 mg kg^{-1} (Table 2). Highest value of Mn was recorded under eucalyptus + turmeric system which was significantly higher than that under all other land use systems. Available Mn in soil was noted under poplar + turmeric system was significantly higher than that under rice–berseem + oat + mustard(fodder)-maize + cowpea (fodder), rice-potato -okra, rice–wheat–green gram, sorghum(fodder)-yellow sarson-black gram, rice–pea(vegetable)-maize, maize–wheat–cowpea, guava + lemon and fallow (uncultivated) land use system. Available Mn in soil noted under guava + lemon system was significantly higher than fallow (uncultivated) land use system.

Sharma and Chaudhary (2003) reported that DTPA extractable Mn was positively and significantly related to the organic carbon content of the soil which might be the reason of high Mn content under eucalyptus + turmeric and poplar + turmeric systems.

It can be concluded from the above study that different land use systems have different impact on the soil chemical properties. Results indicated that with respect to chemical properties of soil agroforestry based systems were found superior followed by field crops, horticultural crops and the uncultivated land. It was found that soil organic carbon content has a significant impact on the chemical properties of soil and as a result, soils with higher organic carbon content were rich in available nutrients.

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