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Research Article

SOIL PROPERTIES AFFECTED BY LAND USE SYSTEMS IN WESTERN CHITWAN, NEPAL

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Abstract

Field experiments were conducted in acidic soils of Mangalpur and Fulbari VDCs in western Chitwan, Nepal to study the effects of different land use systems on soil properties. Seven land use systems (cereal based lowland, cereal based upland, vegetable farm land, fruit orchard land, pasture land, forest land and farmer's field) were used and they were replicated four times in randomized complete block designs. Composite soil samples were collected from each study sites and were analyzed in laboratory for soil physicochemical properties. The data obtained were analyzed using MSTAT-C. Soil properties were significantly affected by land use systems in western Chitwan condition. Soil organic matter and total soil nitrogen were significantly higher from pasture land (4.69 % and 0.23 %) and the lowest were from farmer's field (2.40 % and 0.08 %). However, available soil phosphorous content was significantly higher from cereal based upland (448.3 kg ha^{-1}) and it was the lowest from forest land (13.0 kg ha^{-1}). Soil bulk density and pH were not significantly affected by land use systems. Since land use systems and management practices significantly affect soil physical and chemical properties, an appropriate and sustainable land use management option is necessary for fertile and healthy soil. Conservation tillage with the addition of sufficient organic inputs can be suggested based on this study to maintain soil health for sustained production and optimum activity of soil organisms under the western Chitwan land use systems.

Key words: land use systems; soil properties; soil health; land management; conservation tillage.

Introduction

Nepal is a food deficit country having a population of 26,494,504 with average annual exponential population growth rate of 1.35% (CBS, 2012). With this trend of population increment, it will be more problematic in fulfilling the food demand in future with the existing land resources. Increased human activities caused by increase in population density had been altering the agricultural landscape in Southeast Asia over the last two decades. Shrestha *et al.* (1999) reported rapid change in land use and land cover in Nepal due to the high population growth. In 2009, land area covered by agriculture, forest, pasture and others were 27.99%, 39.60%, 11.99% and 20.42% of the total land area respectively (MoAC, 2010), whereas in the year 2002/2003 agricultural land total was 26.81% (cultivated 20.12% and uncultivated 6.69%), forest 42.76%, Pasture 11.92% and others 18.51% (MoAC, 2004). Although more lands are being used for agriculture, the most fertile lands have been converted into non-agricultural uses in Nepal i.e. for urban areas, industries, road construction, and biodiversity conversion.

Nepal is facing a severe problem of soil quality deterioration and of subsequent low crop yields because of deforestation, overgrazing, burning crop residues, indiscriminate application of agrochemicals and reduced application of organic manures and other land use changes such as use of fertile land for non-agricultural purpose, land fragmentation, use of marginalized areas and slope lands for cultivation. This ultimately causes a decline in SOM, major and minor nutrients in the soil and soil pH (Alfred *et al.*, 2008). Intensive agriculture without application of significant quantity of soil organic matter causes sharp decrease of SOC and organic P (Havlin *et al.*, 2007). Continuous use of agrochemicals in such a land has hazardous effects on plant growth, crop yield and soil properties (Lal and Mathur, 1988). Inappropriate use of land causes environmental degradation and this is a worldwide problem and revived the issue of sustainability in land management. Soil fertility and productivity of any land area depends on the SOM and nutrient content of soil and also on the land use and management practices. Thus to understand the sustainable use potential of the land and associated effects, it is necessary to know the effect of land use on soil properties associated with soil fertility and productivity.

Materials and Methods

Study sites and research design

Fulbari and Mangalpur village development committees (VDCs) located in the western Chitwan, Nepal were purposively selected for this study since these VDCs had all the land use systems proposed for study. Field experiments were conducted with seven land use systems as treatments. Cereal based lowland, cereal based upland, vegetable farm land, and fruit orchard lands were under the management of Institute of Agriculture and Animal Sciences (IAAS) within Mangalpur VDC and were replicated four times at different fields. Farmer's fields represented the land use managed traditionally by corresponding farmer with heavy tillage operation and application of significant amounts of chemical fertilizers and pesticides. Crops generally grown include maize, wheat and vegetables, especially carrot. In Fulbari VDC these were replicated at four different farmer's fields. Forest land and pasture lands were selected and replicated at four different blocks as separated by the Seti Devi community Forest executive body. All together there were twenty eight study sites. The whole experiment was designed in randomized complete block design.

Soil sampling and laboratory analysis

Composite soil samples were collected from each study site from 20 cm depth of land use systems. Soil samples were prepared and stored for laboratory analysis. Air-dried samples were ground, sieved through 2.0 mm sieve and stored for physical and chemical analyses. For SOM analysis samples were sieved through a 0.2 mm sieve. Soil texture, pH, organic matter, total nitrogen, available phosphorus and available potassium contents were analyzed at the Central Soil and Plant Analysis Laboratory of the Institute of Agriculture and Animal Sciences, Tribhuvan University. However, total nitrogen, available phosphorous and available potassium were analyzed in the Soil Science Division, NARC, Khumaltar. Standard laboratory procedures were followed for the analysis of the soil physicochemical properties.

Statistical analysis and data presentation

The data obtained were analyzed using MSTAT-C. Duncan Multiple Range Test and correlations as a measure of inferential statistics were also used for data analysis.

Result and Discussions

Effects of land use systems on soil physical properties

Sand, silt and clay fractions were differed significantly between land use systems (Table 1). The highest sand content (69.36%) was recorded from the cereal based upland and the lowest (34.38%) from the forest land. Similarly, the highest silt (47.33%) and clay contents (18.30%) were found on the forest land. The lowest silt (20.53%) and clay (10.10%) fractions were recorded on the cereal based upland. There was no significant difference in sand, silt and clay fractions of forest land and pasture land though there was slight variation in their content. Sandy loam texture was the textural class on all the land uses except forest land and pasture land where loamy texture was the class (Table 1). As Chitwan land is the second terrace of the Narayani River with alluvial soil, change in the soil texture under different land use systems could be the effect of management.

Soil bulk density was not significantly affected by land use systems in western Chitwan soils. However, the highest soil bulk density (1.41 g cm^{-3}) was observed from cereal based upland and the lowest (0.99 g cm^{-3}) from the pasture land. The reason for the highest soil bulk density from cereal based upland could be due to the highest sand content and destruction of soil aggregates by intensive tillage operation. Due to higher contents of clay particles (Table 1) and soil organic matter (Table 2), the pasture land had the lowest soil bulk density.

Table 1: Effects of land use systems on soil physical properties in western Chitwan, Nepal, 2013

Land use systems	Sand (%)	Silt (%)	Clay (%)	Bulk Density (g cm^{-3})	Soil Textural Class
Cereal based lowland	59.70^{b}	25.38^{bc}	14.93^{ab}	1.30	Sandy loam
Cereal based upland	69.36^{a}	20.53^{d}	10.10^{c}	1.41	Sandy loam
Vegetable farm land	67.49^{a}	22.36^{cd}	10.15^{c}	1.34	Sandy loam
Fruit orchard land	58.78^{b}	27.67^{b}	13.55^{bc}	1.23	Sandy loam
Pasture land	35.95^{c}	46.92^{a}	17.13^{ab}	0.99	Loam
Forest land	34.38^{c}	47.33^{a}	18.30^{a}	1.18	Loam
Farmer's field	57.70^{b}	26.85^{b}	15.45^{ab}	1.39	Sandy loam
LSD (0.05)	5.296^{**}	4.279^{**}	3.768^{**}	NS	
SEM (±)	1.782	1.440	1.268	0.1414	
Grand Mean	54.765	31.006	14.229	1.267	
CV (%)	6.51	9.29	17.83	22.32	

Means followed by the same letter in a column are not significantly different at 5% level of significance as determined by DMRT

**.Significant at 0.01 level

Table 2: Soil chemical properties affected by land use systems in western Chitwan, Nepal, 2013

Land use systems	**SOM (%)**	**N (%)**	**P_2O_5 (kg ha^{-1})**	**K_2O (kg ha^{-1})**	**pH**
Cereal based lowland	3.01^{cd}	0.13^{c}	17.00^{c}	27.25	5.49
Cereal based upland	2.79^{cd}	0.09^{d}	448.3^{a}	90.00	5.63
Vegetable farm land	2.58^{d}	0.15^{c}	375.3^{a}	86.50	5.41
Fruit orchard land	3.75^{b}	0.18^{b}	83.75^{bc}	120.5	5.68
Pasture land	4.69^{a}	0.23^{a}	15.25^{c}	72.75	5.74
Forest land	3.42^{bc}	0.19^{b}	13.00^{c}	79.50	5.36
Farmer's field	2.40^{d}	0.08^{d}	119.3^{b}	88.25	5.20
LSD (0.05)	0.6441**	0.01914**	83.54**	NS	NS
SEM (±)	0.2168	0.006442	28.12	26.23	0.2382
Grand Mean	3.236	0.153	153.107	80.679	5.505
CV (%)	13.39	8.70	36.73	65.01	8.66

Means followed by the same letter in a column are not significantly different at 5% level of significance as determined by DMRT
**.Significant at 0.01 level

Effects of land use systems on soil chemical properties

Soil organic matter is an important and dynamic property of soil. It affects most of the soil properties like water holding capacity, cation exchange and the nutrient supplying capacities of soil. Soil organic matter was affected significantly by changes in land use systems. The highest amount of soil organic matter (4.69 %) was recorded from the pasture land whereas the lowest (2.40 %) was from the farmer's field (Table 2). Cultivation intensifies soil organic matter decomposition whereas non-cultivated land preserves it. Hence, the pasture and forest lands and fruit orchard contained more SOM than the other four land use systems (Table 2). The lower levels of SOM from farmer's field, cereal based upland, cereal based lowland and vegetable farm land could be the result of high OM decomposition, insufficient organic materials inputs in the systems, residue removal and lack of crop rotation (Duff *et al.*, 1995; Grace *et al.*, 1995). Rapid mineralization and loss of carbon from the soil might be another reason for low organic matter content in cultivated land use systems. Unger (1982) reported lower soil organic matter content from intensively tilled field. Light textured soil of farmer's field might also be a cause of lower organic matter content. Light textured soil contains higher amount of sands than clay fractions. Sands have less exchange surface and thus adsorb less OM (Brady and Weil, 2005). This might be the reason of lower organic matter content in light textured farmer's field. Thus, higher contents of soil organic matter from pasture and forest lands could be due to high organic matter synthesis and accumulation, and higher clay content (Table 1). This might be apparently due to substantial exchange surface area on clay particles than on sand particles. Clay particles adsorbed and stabilized more OM and other nutrients (Saggar *et al.*, 1994 and 1996) in pasture and forest lands.

The magnitude of residual total soil nitrogen varied greatly with the production system and adopted crop and land management practices. Nitrogen content of soil was significantly affected by the land use systems. Total soil nitrogen content was the highest (0.23 %) from pasture land and the lowest (0.08 %) was from farmer's field (Table 2). There was a strong positive correlation ($r = 0.773^{**}$) between soil organic matter and total soil nitrogen contents (Table 3). Thus, the lower contents of total soil nitrogen from the farmer's field and other cultivated land use systems might be due to lower amounts of soil organic matter. Frequent tillage operation causes rapid mineralization of soil organic matter and organic nitrogen and transforms them in to mineral N, CO_2 and nitrogenous gases that escape into the atmosphere and are lost from the soils. This could lead to lower nitrogen content in farmer's field. There was more N harvest and low external input in the farmer's field due to crop intensification. The low inputs in subsistence farming cannot compensate for nitrogen losses in the system and lead to decline in total soil nitrogen. Subsistence farming in Nepal is based upon lower input of chemical fertilizers. Though amount of fertilizer use in Nepal increased from 17.02 kg ha^{-1} in 2007 to 23.2 kg ha^{-1} in 2012 (FAO, 2013), it is not sufficient to compensate for the losses. In low input agriculture organic matter serves as a source of plant N, P and S. Thus, in the field lower content of soil organic matter leads to decline in N, P and S contents in soils and finally affects soil productivity and sustainability. A land use change from natural forest to cultivated land aggravates land degradation and reduces the quantity of soil N content over the long run. Runquan (2002) reported a decrease in soil organic matter and total nitrogen due to deforestation. Fu *et al.* (2001) also found 18% increment in total soil N when farm lands were converted back to forest land. This increase in total soil N might be due to fixation of atmospheric nitrogen by the trees, shrubs, and grasses when farm lands were converted back to forest land. Better nutrient cycling in the forest soil compared to other land use systems which have continuous mining of nutrients from the soil might be another reason for increase in total soil N in forest land.

Table 3: Simple correlation coefficients of soil characteristics of western Chitwan soils, 2013

	N	P_2O_5	K_2O	Bulk density	pH
SOM	0.773**	-0.423*	-0.025	-0.156	0.293
N		-0.493**	0.046	-0.400*	0.233
P_2O_5			0.274	0.353	0.106
K_2O				0.265	0.264
Bulk density					-0.020

*. Significant at 0.05 level
**.Significant at 0.01 level

Available soil phosphorous was affected by the land use systems. The highest available phosphorous (448.25 kg ha^{-1}) was recorded from the cereal based upland and that of the lowest (13 kg ha^{-1}) was observed from the forest land. There was no significant difference in available P between pasture and forest lands. Cereal based upland and vegetable farm land were similar in available P content (Table 2). Low level of available P from the pasture land, forest land and cereal based lowland might be due to higher clay content. The amount of P fixation depends directly on the exposed reactive surface area of clay particles. Clay has more exposed reactive surface area than silt or sand. Therefore, P fixation is greater in soil having higher clay content (Havlin *et al.*, 1990). Low levels of available P from the forest soil might also be due to the forest vegetation itself with large biomass and thus more P uptake and immobilization in plant biomass. Phosphorous shows a tendency to build up in soil with subsequent addition of phosphatic fertilizers from external sources. The residual effect of added phosphatic fertilizers might have caused a high level of phosphorous from the cereal based upland and vegetable farm, but such an effect in the cereal based lowland may have been overridden by the higher clay content.

Effects of land use systems on available soil potassium are presented in Table 2. The highest (120.5 kg ha^{-1}) amount of available K was found in the fruit orchard land and that of the lowest (27.25 kg ha^{-1}) in the cereal based lowland. Available soil potassium was not significantly affected by land use systems (Table 2). The lowest (27.25 kg ha^{-1}) amount of available soil potassium determined in the soils of cereal based lowland compared to other land use systems might be due to higher leaching loss of potassium from soil surface, more K harvest from the soil, crop intensification and low external input. Kanwar (1976) reported the higher K leaching loss from humid tropics as a major factor of limiting productivity but the leaching under natural vegetation was low (0 to 5 lbs/a/yr). However, the loss might exceed more than 35% of applied K on cleared land and much higher on bare land. The continuous loss of available K from soil might have also caused low content of K from the pasture land and other cultivated land use systems. Application of acid forming fertilizers in cereal based lowland could have contributed to available K depletion as reported by Baker *et al.* (1997) and Wakene (2001). The higher available K in the fruit orchard land might be due to recycling of nutrients. The damaged fruits and shed leaves are mixed with soil and undergo recycling to release K. The burning of plant litter in the orchard might be another reason for higher available K content. Relatively higher soil pH might have also contributed to higher K content from the fruit orchard land (Table 2). Mesfin (1996) also reported high K content under high pH tropical soils.

Soil pH is a measure of acidity or alkalinity. Soil pH influences the availability of soil nutrients to plants and the nutrient interactions. Soil pH measured from the field in western Chitwan with different land use systems in 1:1 soil water solution ranged from 5.2 to 5.74 and was not significantly affected by the land use systems. Soils from all the land use systems were found to be slightly acidic. However, soil acidity was the highest from the farmer's field. This might be due to continuous cultivation and use of nitrogenous fertilizers that accelerated soil acidification. Lower soil pH from the farmer's field could be due to depletion of basic cations or due to higher microbial oxidation that produces organic acids causing lower soil pH (Tilahun, 2007).

Conclusions

Soil properties are significantly affected by land use systems and land management. A change in land use systems cause reduction in soil organic matter and other soil nutrients responsible for soil fertility and productivity and lead to soil degradation. Conservation tillage with the addition of sufficient organic inputs can be suggested based on this study to maintain soil health for sustained production and optimum activity of soil organisms under the western Chitwan land use systems.

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