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Research Article

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Variation of soil properties under different land use systems in mid-hills of Nepal

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ABSTRACT

This research was conducted in four VDCs of Darechok from Chitwan, Sarangkot from Kaski, Tilhar from Parbat and Bhatkhola from Syangja including two components of field research survey and soil sampling in 2014/2015 to determine soil properties in different land use systems in relation to soil erosion and landslide. This was designed as a factor randomized complete block design with six treatments and land use systems replicated four times. There were six types of predominant land use systems namely perennial orchard, forest, maize based, vegetable based, fallow and rice based lands. Among different districts, soil of Kaski was loamy and that of Chitwan, Parbat and Syangja was sandy loam. Among the treatments, maize based system has the highest bulk density as compared to soils from other cropping systems while moisture percentage was the highest in rice based land use systems. The highest pH (6.02) in maize based agricultural land and that of the lowest (4.6) in forestland systems were observed. The highest organic matter (5.95 %) and nitrogen content (0.3050%) were in forests. Phosphorus was found significantly higher (98.25 kg/ha) in vegetable land. There was a positive correlation (R^2=0.5381) between nitrogen and organic matter content and organic matter content and phosphorus content (R^2=0.1026). The highest value of potassium (312 kg/ha) was detected in soils from maize based systems. Among different land use systems, forestland contains relatively higher amounts of nutrients than others. From both the risk factors and soil fertility point of view forest land use systems were the best among the treatments.

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INTRODUCTION

The elevation of mid-hill regions of Nepal ranges from 50-4000 masl (meter above sea level), and the majority of the land is sloppy. Nepal is an agro-based country where agriculture shares 35.12% of the total GDP and provides employment to 65.6% of the total population (MoAD, 2012/2013). Farmers follow agricultural practices based on their traditions to feed the expanding population. Farmers have even been cultivating sloppy lands which are hazardous to cultivate as per land capability classification (Pandey & Sirothia, 2009). Because of faulty agriculture practices and the cultivation of more sloppy land, soil erosion accelerates which invites landslides upstream and floods downstream leading to lowland disasters (Forsyth, 2005; GON/MoHA, 2019). Depending on the nature of the land, and the farmer's interest, there are different cropping patterns. These patterns determine the physico-chemical properties of soil. Multiple tilling has greater disturbance in soil structure that affects the physico-chemical properties and increases surface runoff that may affect the nutrient availability to the crops (Atreya *et al.*, 2008). Variation in soil properties affects land productivity, sustainability and stability of the soil which ultimately affects soil erosion, downstream flooding and risk of water-induced disaster.

Nutrients could differ from place to place, and spatial variability was predicted by the scientists/organization which helps to increase the soil fertility and productivity and increase the agriculture production by minimizing the soil loss from the plain and hilly region of Nepal.

The long-term sustainability of cropping systems is largely determined by their impact on soil quality, particularly in soil physical and chemical properties of soil. Cropping systems could be advantageous for developing in good quality of soil because soil quality is directly related to the capacity of soil to function (Karlen *et al.*, 1997). Fertilizer type, litterbag mesh size, and climate did not influence the litter decay response to N additions (Knorr *et al.*, 2005).

Extreme weather events are creating environmental problems, accelerating the rate of erosion, and threatening agricultural production needed for food security (Cerri *et al.*, 2007). In Nepal, the 'Panchase' area has been identified as a pilot site to assess vulnerability to the impacts of climate change on water resources, agriculture and biodiversity (IUCN, 2015). This panchase region from the three districts Syanga, Kaski, and Parbat is vulnerable to disaster risk prone.

MATERIAL AND METHODS

This research was conducted in Kaski, Syangja, Parbat and Chitwan districts of Nepal to evaluate the distribution of the soil properties under different land use systems.

Selection of Site

Different land use system is selected to determine soil properties under different land use systems of mid-hills, four districts of mid-hill Nepal namely Chitwan, Kaski, Parbat and Syangja were selected where IUCN-EPIC project was launched in three districts (Kaski, Parbat and Syangja). Within these districts, Darechok VDC from Chitwan, Tilahar VDC from Parbat, Bhatkhola VDC from Syangja and Phewa lake area of Sarangkot VDC of Kaski were selected based on accessibility and demonstration area of Ecosystem Protecting Infrastructure and Community (EPIC) project of IUCN.

Experimental Design and Treatment Structure

In each study site, there were six types of predominant land use systems such as perennial orchard, forest land, maize based agricultural land, vegetable based agricultural land, fallow and rice based agricultural lands. Each land use system is considered as treatment. The treatments detail is given in the Table 1.

Soil Sampling & Soil Analysis

Soil samples from four farmers were collected from a depth of 20 cm and composited for each land use system. Soil samples were collected on June 15, 2021. There were six land use systems and a total of 24 samples were collected. All samples were taken to the Regional Soil Testing Laboratory, Pokhara and AFU soil Lab to analyze the chemical properties of soil (Table 2). To determine the Bulk density and moisture percentage of soil, another four soil samples were taken from the farmer's field for each land use system and oven dried. The average of four samples calculated is considered representative for a particular land use systems. Altogether there were 96 cores were taken. Bulk density and moisture percentage were determined by the following formula;

$$\text{Bulk density (g/cm}^3) = \text{Dry soil weight (g)/Soil volume (cm}^3)$$

$$\text{Moisture Percentage} = (\text{Mass of water when saturated/mass of dry soil})*100$$

Table 1: Distribution of treatments in each districts experimental area

Treatments	Symbol
Forestland	T1
Perennial orchard land	T2
Fallow land	T3
Vegetables based agricultural land	T4
Rice based agricultural land	T5
Maize based agricultural land	T6

Soil color was observed with the help of a Munsell color chart describing *HUE, VALUE, CHROMA*.

Data Analysis & Presentation

The data were analyzed by descriptive and inferential statistics. All the data were analyzed by the computer software program M-STATC. The results of the experiment were based on the output of the Analysis of the Variance (ANOVA) and DMRT test. Computation and preparation of graphs were done using the Microsoft Excel 2007 Program.

RESULTS AND DISCUSSION

The results of the study were conducted in the mid-hills of west Nepal to find out the soil properties distribution under different land use systems in relation to soil erosion and downstream risk factors.

Physical Properties

Soil physical properties analyzed in this research were soil texture, soil color, bulk density (BD) and moisture content of the soil. The soil of Sarangkot, and Kaski was loamy and that of Darechok, Tilhar and Bhatkhola was sandy loam (Table 3). The texture is dominated by sand and silt content, and very little clay indicating the soils are easy to erode by monsoon storms especially Sarangkot where sand and silt share almost equal amounts. Both these textural contents have less cohesion and easily detached by the rain drops.

Bulk Density

Bulk density was notable a difference under different cropping systems. Maize based land use had a higher bulk density (1.72 gm/cm^3) followed by vegetables based cropping system with 1.54 gm/cm^3. Forest land and rice land are almost similar in bulk density. The lowest bulk density is observed in land growing orchards (1.328 gm/cm^3) (Table 4). The highest bulk density (1.53 gm/cm^3) was found in Chitwan and the lowest (1.41 gm/cm^3) in Syangja.

Moisture Percentage

Moisture percentage was significantly different among different land use systems (Table 5). The highest level of moisture percentage (35.15%) was observed in rice based agricultural land and the lowest was (20.88 %) in fallow land

Table 2: Physico-chemical analysis method done by the Regional Soil Testing Laboratory (RSTL), Pokhara

Parameters	Analysis methods
Soil texture	Hydrometer & Texture classification following USDA system (Day, 1965)
Soil organic matter	Modified Walkey and Blacks' titration wet digestion method.
Total nitrogen in soils	Microkjeldhal distillation unit using $K_2Cr_2O_7$ as oxidizing agents with conc. H_2SO_4 digestion and back titrated with dilute HCL (Bremner, 1965)
Available phosphorus	Modified Olsen method – Sodium Bicarbonate extraction and color developed with ascorbic acid blue color and detected in 546 nm (Olsen & Dean, 1965).
Soil pH	Beckman glass electrode pH meter (Wright, 1939)
Potassium	Neutral Ammonium acetate extraction (Flame photometer)
Bulk density	Undisturbed soil core sampling and Mass/volume

Table 3: Texture determination by Hydrometer method

	Sand	Silt	Clay	Classification	BD (gm cm^{-3})
Darechok, Chitwan (R_1T_1)	56.3	32	11.7	Sandy Loam	1.53
Sarangkot, Kaski (R_2T_3)	42.6	44	13.4	Loam	1.41
Tilhar, Parbat (R_3T_4)	60.6	24	15.4	Sandy Loam	1.47
Bhatkhola, Syangja (R_4T_2)	58.3	25.3	16.4	Sandy Loam	1.45

(Table 5). There was a significant difference in moisture soil content among the districts. The highest moisture content (33.105%) was determined in Kaski and that of the (20.22%) was in Chitwan.

RESULTS

Total soil N content was increased with an increase in organic matter content in all treatments & districts. The soil organic matter and total nitrogen contents were positively correlated (R^2=0.5381) (Figure 1).

Co-relation between Soil Organic Matter and Available Phosphorus in different Land Use Systems

In this correlation graph organic matter and phosphorus content/availability were prevented. Available phosphorus content was higher in the soils having high soil organic matter. There was positive correlation (R^2=0.1026) between soil organic matter & available phosphorus (Figure 2).

Physical Properties

According to texture classification, there is a high sand percentage in Parbat so bulk density would be lower. In another case, silt percentage is higher in the Kaski area so there may cause more siltation and losses could occur. Sedimentation of eroded soil in the Phewa Lake area could be reduced by vegetative planting in risk prone areas.

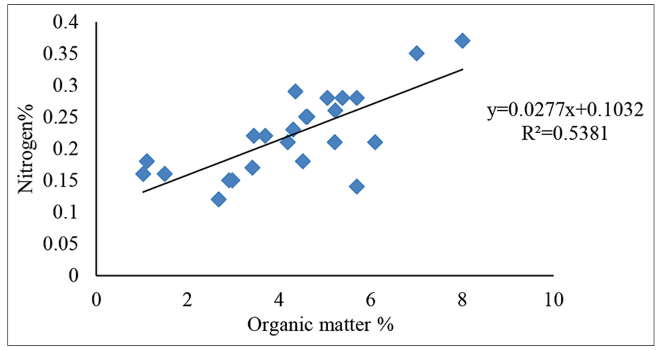

Figure 1: Correlation between the soil organic matter and the total nitrogen contents (Soil sample analysis, 2015)

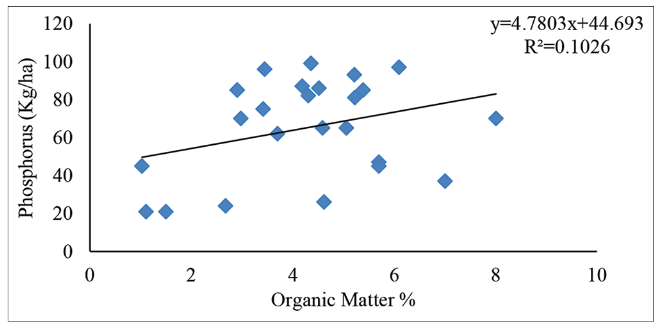

Figure 2: Correlation between the soil organic matter and available phosphorus contents in soils of different land use systems

In the case of bulk density of soil properties, it was documented by Azam *et al.* (2008) that bulk density and porosity was proved to be significantly better in maize-fallow systems. This also coincides with our result in the bulk density section. If the bulk density is appropriate for root growth, there would be excellent aggregate stability, moisture and temperature level. Since it was sandy loam soil in the field, it would be appropriate at 1.60 gm/cm^3. Moreover, if there is high organic matter, well aggregated in the cropping system, there is a chance of low bulk density. Since there is also low compaction in the fallow, forest and orchard based cropping system, there would be a chance of low bulk density. On the other hand, rice based, maize based and vegetable based have high compaction due to the shallow root system, this may cause high bulk density (>1.4 gm/cm^3) in four districts of Nepal. Also, if the sand percent is high in the soil, our result shows a high percent of sand in vegetables, this is why bulk density is higher than in forest and fallow treatments.

In the case of Moisture percentage, Clay soils hold more water for longer, which is supported by Tripathi and Jones (2010). In our result, rice soils are more clayey type than other cropping systems so this soil has the highest soil moisture retention capacity. We collected soil just before the rainy season, so it is benefitted by water holdings. Since there is no vegetation in fallow land, there seems to be an absence of moisture percentage.

In our result, Black soils for instance are considered to have better moisture retention, internal drainage and texture, making

Table 4: Mean squares for two-way analysis of variance for soil chemical properties due to land use, districts and error

Source of Variation	df	BD	Moisture %	pH	OM (%)	Total N (%)	Available P (Kg/ha)	K_2O (Kg/ha)
Land use system	5	0.083**	127.08*	1.046*	8.38**	0.011**	2005.9*	35622**
Districts	3	0.01437	188.68**	1.783**	2.39	0.0015	325	2752
Error	15	0.013	33.72	0.275	1.32	0.002414	481.7	3322

LU=Land use, BD=Bulk Density, K_2O=potassium, OM=organic matter, df=degree of freedom, *Significant at 0.05, **Significant at 0.01

Table 5: Main effects of land use systems on soil pH, organic matter, total nitrogen, available phosphorus and available potassium

	Bulk Density (gm/cm^3)	Moisture percentage	pH	Organic Matter %	Nitrogen %	Available Phosphorus Kg/ha	Potassium Kg/ha
Maize based	1.72^a	23.78^c	6.025^a	4.43^a	0.1850^{bc}	63.00^b	312.00^a
Vegetable based	1.54^b	25.61^{bc}	5.825^a	4.31^a	0.2325^{abc}	98.25^a	285.75^a
Orchard based	1.33^c	29.15^{abc}	5.725^a	4.73^a	0.2525^{ab}	64.5^b	238.25^a
Rice based	1.45^{bc}	35.15^a	5.700^a	4.71^a	0.2000^{bc}	63.75^b	116.50^b
Fallowland (BARE)	1.35^c	20.89^c	5.500^a	1.58^b	0.1550^c	27.75^c	114.00^b
Forest-based	1.44^{bc}	33.66^{ab}	4.575^b	5.95^a	0.3050^a	58.50^{bc}	105.50^b
LSD	0.1618	8.75	0.79	1.73	0.074	33.08	86.87
SEM(±)	0.048	3.6	0.36	0.558	0.132	9.46	25.045
CV	7.3	20.7	9.43	26.83	22.17	26.02	29.5

SEM=standard error of mean, LSD=Least significance difference at 0.05% & 0.01%, CV=coefficient of variation. Co-relation between soil organic matter and total nitrogen content

management practices such as labour, compost, and fertilizer application easier and giving higher yields.

Chemical Properties

According to the result, in the case of PH, this is because the forest land use system releases more hydrogen ions than maize based cropping systems. In other cases, maize based, vegetable based, orchard based, rice-based and fallow based are not statistically different from other cropping systems, but the average is different from each other. Another research conducted by observed acidification of forestland coincides with the results of Geissen *et al.* (2009) for tropical soils.

It was in accordance with the findings of Islam and Weil (2000), who reported that organic carbon is highest in reforested soil (12.8 g/kg), whereas organic carbon is lowest in cultivated soil among four different cropping systems. Havlin *et al.* (1989) concluded that no tillage has higher organic carbon than no tillage. Furthermore, Vitousek and Sanford (1986) added that organic matter is higher in tropical forest if moisture factor is excluded.

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