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Carbon sequestration Potential and Chemical Characteristics of Soil along an Elevation transect in Southern Himalayas, Nepal

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Abstract

The study was aimed at quantifying and comparing the amount of carbon stored in soil and chemical parameters of soil at different elevations under different land uses. Soil samples were collected from the surface (0–10 cm) and subsurface (10–20 cm) soil layers at Dhunche and from five other sites samples were randomly chosen at four different locations at each site. Samples were collected during May at different elevation (approximately 500m change in elevation) in forest land uses and grassland use. Soil of the study area was slightly acidic to alkaline in nature. The dominant textures were sandy loam and loamy sand. Biomass was gradually increased at north with increasing altitude whereas at south aspect biomass was increased up to 3650m and then gradually decreased. SOC stock was high at the highest elevation and similar trend was seen at other sites. SOC was gradually decreased with increasing soil depth. Soil nutrients (NPK) were found to decrease with increase in altitude. The results from the present study also suggest that the Himalayan soil have a great potential to store the carbon. The present study provides the dataset on soil physical and chemical properties and paves a way for further study in the region.

Keywords: Carbon sequestration, altitude, SOC, soil nutrients, Himalayas, Nepal.

Introduction

Soil Organic Carbon (SOC) makes up a huge amount of the terrestrial carbon pool which is regarded as part of the global carbon cycle. It plays an important role in mitigating climate change and guaranteeing food security worldwide. Soil carbon sequestration has much to recommend climate change mitigation, land as well as livelihood protection including resilience to climate change. Moreover, soil also plays a important role in the global carbon budget and greenhouse effect. Soil Organic Matter (SOM) can act both as a sink and a source of carbon in response to climate, different land use changes, and to the rising CO_2 levels in the atmospheric[1,2]. Small changes in SOM could influence long-term ecosystem sustainability, the global carbon budget and the atmospheric CO_2 concentration[3]. High altitude terrestrial ecosystems are considered as important components in the global carbon cycle and stores large reservoirs of soil organic carbon (SOC).

SOM includes all living and non-living organic material in the soil[4]. In general, about two-thirds of earths carbon is sequestered in the standing forests, leaf and forest debris, and in forest soils[5]. Forest vegetation and soils share upto 60% of the world's terrestrial carbon in common[6]. Vegetation and soils may significantly add to mitigation of global climate change as they are natural sinks for atmospheric carbon (C)[7-10].

Moreover, soil organic matter can also increase or decrease that depends on various factors including: climate, vegetation type, nutrient availability, disturbance, and land use and management practices[11,12]. In addition, physical soil properties, for example soil structure, particle size, and composition, has significant impact on soil carbon (C). Further, soil particle size also has a strong influence on the rate of decomposition of soil organic carbon[1].

The macronutrients: nitrogen (N), phosphorus (P) and potassium (K) are deficient in the soil as plants require them in the largest quantities. These soil nutrients are considered to have a close relation with the soil organic matter as a significant proportion of N and P are released through decomposition of organic residues in soil. They often serve as good chemical indicators of the status or quality of the soil. Moreover, terrestrial carbon and nitrogen coupling has increasingly received research interest over the decades because of the progressive nitrogen limitation on future carbon sequestration in terrestrial ecosystems[13].

Nepal is a Himalayan country which is one of the remote and isolated regions with complex terrain[14]. Due to remoteness, high altitude and harsh climate conditions; sampling and monitoring is very difficult in the region[15,16]. Till date there is limited published data on soil physical and chemical composition in the Nepal Himalayas. Thus, there is a need for understanding the carbon stocks and soil properties varying at different land use with change in elevation.

Therefore, we selected different locations at different elevation transect (1900 to 4410 m a.s.l) for evaluating soil carbon stocks. In this study we aim to quantify and compare the amount of carbon stored in soil at different elevations and under different land uses in the central Himalayas, Nepal. Moreover, we also access the physical properties (bulk density, soil texture) and Chemical properties (pH, macronutrients – N, P, K) in the Himalayan soil at different altitude.

Material and Methods

Study area: The study was carried out in six different elevation transect in forests and grasslands in Langtang National Park, Nepal from (1930-4410 m.a.s.l). The higher elevation gradients coupled with complex topography and geology has enriched a rich biodiversity, vegetation belts and different soil features in the study area. Langtang National Park is the nearest national park of the capital city Kathmandu in the Central Himalayan Region. The study was done from 85° 18.503' - 85° 24.90' E longitude and 28° 06' - 28° 04.91' N latitude from Dhunche to Goshainkunda. Details on sampling sites have been presented in figure-1 and table-1.

Table-1
Sampling sites description

Sites	Elevation (m)	Land-Use
Dhunche	1935	Forest / Agriculture
Deurali	2795	Forest/ Agriculture
Chandanbari	3184	Forest
Cholangpati	3617	Forest
Lauribinayak	3973	Shrub land
Gosainkunda	4404	Alpine meadows

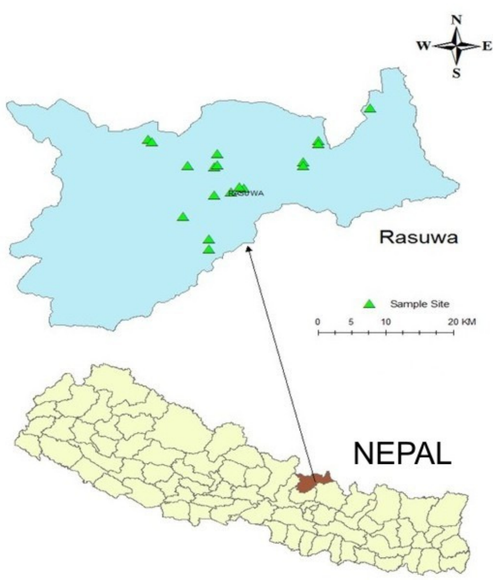

Figure- 1
Map showing the sampling locations of soil

Soil Sampling: Top soil samples were collected from the surface (0–10 cm) soil layers 5 sites and (0-10 and 10-20cm) at lowest elevation site Dhunche. At each location four soil sampling sites were randomly chosen from about 50 meters distance to make a replicate sample representative of each location. Sample collection was done during May, 2011 at different elevation (approximately 500m change in elevation) in forest land uses and grassland use. Soil samples for bulk density (BD) analysis for each depth were found with core samplers (which was 5 cm in diameter and 6 cm high). Bulk soil samples to measure and compute average soil parameters were collected randomly from four different points at each sampling locations, and transferred to zip-lock plastic bags. A total of 28 samples were collected and analyzed in the Aquatic Ecology Centre, Kathmandu University.

Laboratory analysis: The details on laboratory methods used are presented in the table-2.

Table-2
Methods used for Laboratory analysis

Parameters analyzed	Methods used
Bulk density	core method
Soil organic matter (SOC)	dry combustion method
Soil texture	soil hydrometer method
soil pH	pH probe
Total N	Kjeldahl digestion–distillation method
Total P	Modified version of Olsen's method
Total K	Flame photometer emission method

Results and Discussion

Soil physical parameters: The physical characteristics of soil from our sampling locations were analyzed and shown in figure-2. The bulk density of the soil reflects the level of compaction and amount of pore space in the soil. There was no significant change observed in bulk density value at varying altitude at our study sites. However, SOC% was found to be lowest in the Dhunche, lowest elevation soil sampled. Soil organic matter can also increase or decrease due to nutrient availability, disturbance, and land use and management practices. This is due to the human disturbance in the site as it was close to the human settlement. However, other sites had comparatively similar trend in the SOC% and slightly higher at the highest elevation. Previous studies have suggested that decrease in temperature and increase in precipitation with increasing altitude changes in climate along altitudinal gradients can influence the composition and productivity of vegetation and, as a result of these can affect the quantity and turnover of SOM[17,18,19]. Similarly, study done by Sims Z.R. and Nielsen G.A.[20] indicated that the relationship between SOM and altitude has positive correlations. Similar, results was observed in this study.

Another important physical factor in the soil is pH, which determines the acidity and alkalinity of the soil. From, figure-2 we can see that the soil in the regions are slightly acidic to alkaline but no clear trend with altitude. Texture is the distribution of different size fractions of particles. Texture is an expression that characterizes the relative amounts of sand, silt and clay in the soil. The soil texture in the study region has been presented in table-3.

The results showed that the central Himalayas soils falls in the 3 categories of USDA defined textural classes such as Silt Loam, Sandy Loam and Loamy Sand. The two low altitude sites had a Silt Loam and another consecutive sites and highest altitude site fell on Sandy Loam. Only one site fell on Loamy Sand category. This explains that the silt and sand percentage are higher in the soil sampled at different sites.

Carbon stock density at the sampling sites: The carbon stock density of soil organic carbon was calculated as described earlier by Pearson T.R. et.al.[21]:

SOC stock=$\rho \times d \times$SOC%,

Where: SOC stock = soil organic carbon stock per unit area [t ha^{-1}], ρ= soil bulk density [g cm^{-3}], d=Total depth at which sample was taken [cm], and SOC= carbon concentration [%].

The soil carbon stock density was calculated for all 4 samples collected from each sites. This gives the measure of tons carbon sequestered per hectare of soil in the region. The average calculated value of soil carbon stock has been presented in figure-3.

It is clear from the figure-3 that SOC stock density (tHa^{-1}) was found to be consistent at different elevation at 5 sites. However, the highest SOC stock was observed at Gosainkunda at the highest altitude (4404m) sampled. The consistency of SOC stock at 5 sites may be due to the samples collected from the forest soils. In case of the last sampling point the sample was collected from the alpine meadows. The lowest SOC stock was found to be at Dhunche, lowest elevation site which is because of the disturbed land use due its closeness to the human settlements that enhance the disturbances in the soil due to cattle and horses and over grazing. These results clearly revels that the soil carbon sequestration rate is higher in the less disturbed high altitude soil which have already been discussed in the above section.

Table-3
Sand, silt and clay percent and USDA textural class of soil in Nepal Himalayas

Sites	sample no.	Clay%	Sand%	Silt%	USDA textural class
Dhunche	1	6	37.86	56.14	Silt Loam
	2	9	37.67	53.33	Silt Loam
	3	8	38.14	53.86	Silt Loam
	4	7	37.76	55.24	Silt Loam
	Mean ± SD	7.5 ±1.29	37.85 ±0.203	54.64 ±1.282	
Deurali	1	8	40.56	51.44	Silt Loam
	2	9	41.36	49.64	Silt Loam
	3	10	40.68	49.32	Silt Loam
	4	8	41.08	50.92	Silt Loam
	Mean ± SD	8.75 ±0.957	40.92 ±0.368	50.33 ±1.012	
Chandanbari	1	6	62.26	31.74	Sandy Loam
	2	7	60.16	32.84	Sandy Loam
	3	5	60.98	34.02	Sandy Loam
	4	8	61.36	30.64	Sandy Loam
	Mean ± SD	6.5 ±1.290	61.19 ±0.871	32.31 ±1.451	
Cholangpati	1	8	69.74	22.26	Sandy Loam
	2	7	69.04	23.96	Sandy Loam
	3	9	68.78	22.22	Sandy Loam
	4	7	69.34	23.66	Sandy Loam
	Mean ± SD	7.75 ±0.957	69.225 ±0.41	23.025 ±0.41	
Lauribinayak	1	6	80.64	13.36	Loamy Sand
	2	9	78.88	12.12	Loamy Sand
	3	7	79.22	13.78	Loamy Sand
	4	10	80.06	9.94	Loamy Sand
	Mean ± SD	8 ±1.825	79.7 ±0.799	12.3 ±0.799	
Gosainkunda	1	6	68.98	25.02	Sandy Loam
	2	8	69.07	22.93	Sandy Loam
	3	6	67.93	26.07	Sandy Loam
	4	7	68.05	24.95	Sandy Loam

Mean ± SD	6.75 ±o.957	68.507 ±0.60	24.74 ±0.600

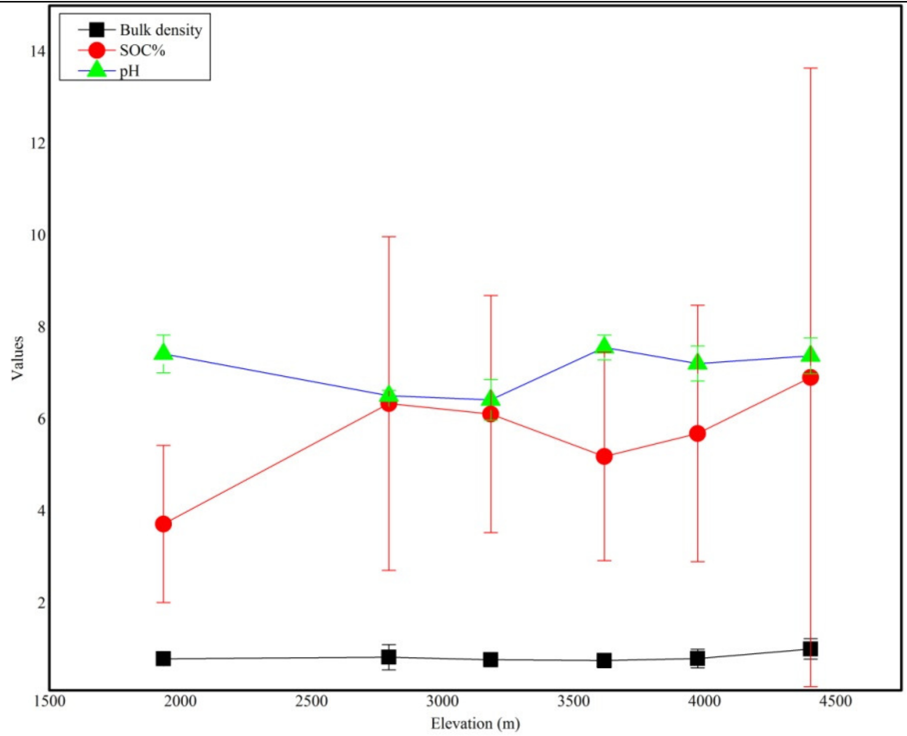

Figure- 2
Soil physical characteristics at different altitude

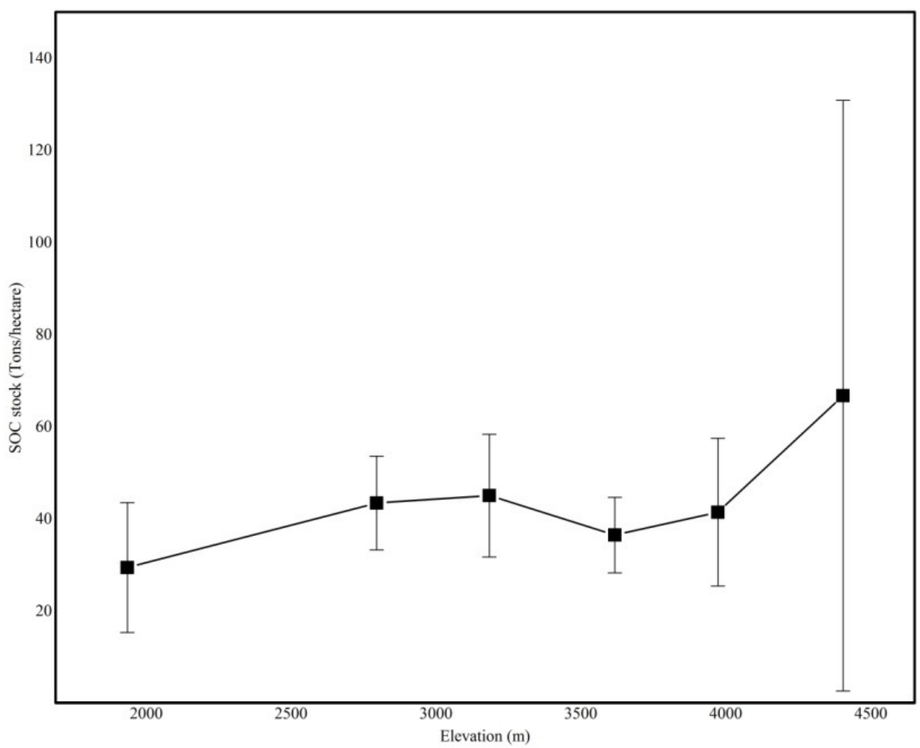

Figure-3
Average soil organic carbon stock at different elevation in the study area

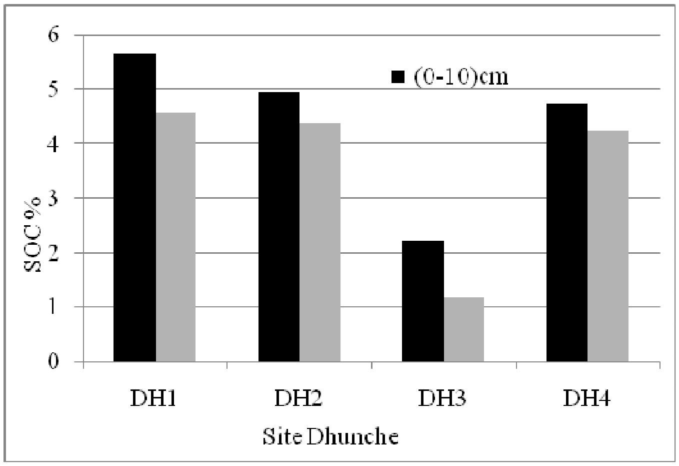

Figure-4
Bar graph of soil organic carbon at different depth

Soil organic carbon at (0-10 and 10-20 cm) depths at Dhunche: The soil organic carbon percentage at different soil depths (0-10 and 10-20 cm) were analyzed and presented in the figure-4. The results showed that the SOC% decreases as depth increases. SOC gradually decreased with increasing soil depth. As there are higher organic matter in the top layer soil, the percent of organic carbon is higher in top soil. The higher concentration of soil organic carbon in top layer than in lower layer has also been reported by various authors[22,23] in the past and our results also showed the similar trend.

Chemical characteristics of the Soil: The concentrations of soil nutrients Nitrogen (N), Phosphorous (P) and Potassium (K) in soil samples at different altitude are shown in figure-5. It is clear that the N, P and K concentration has a negative or inverse relation with altitude i.e. with increase in altitude decrease in concentrations was observed in this study. The highest concentrations of nutrients were found in the lowest altitude and lowest concentrations in the highest altitude explaining the loss of nutrients in the higher elevations. The highest concentrations of NPK in soil are due to the inorganic fertilizer availability in the lower altitude soil[24] close to the agricultural areas and human settlements. Our results showed the good nutrients in the sampled soil and when compared to the agricultural soil in the India[25].

Conclusion

Physiochemical properties of soil at different elevation transect from Nepal were investigated. The results showed that Himalayan soil had huge potential to store carbon and may be useful to combat climate change. SOC% gradually decreased with increasing soil depth. The central Himalayas soils falls in the 3 categories of USDA defined textural classes such as Silt Loam, Sandy Loam and Loamy Sand. The soil in the regions is slightly acidic to alkaline but no clear trend with altitude.

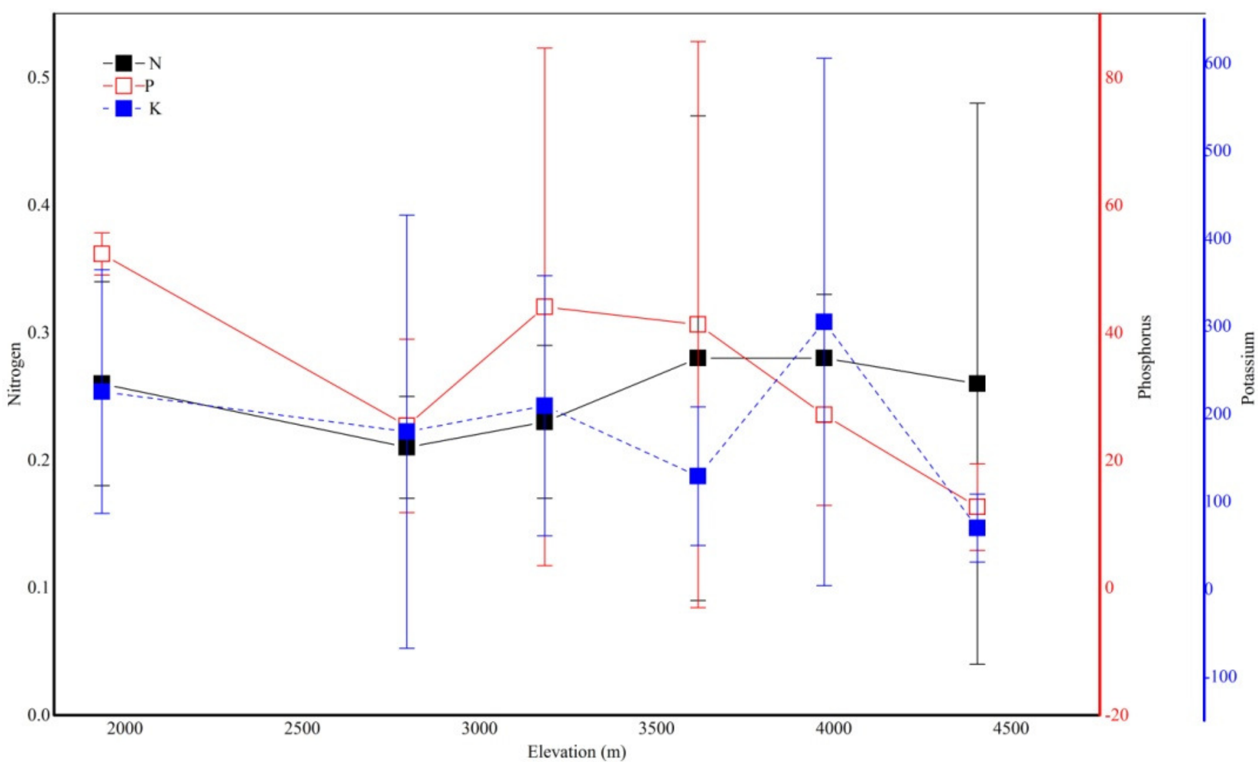

Figure-5
N, P and K concentrations in soil at different elevations in ppm

The soil properties were found to change randomly with altitude along all studied areas. Sampled soils were found to be richer in organic matter, slightly acidic, and less fertile which was indicated by decreasing nutrient concentrations with increasing altitude in the study area. However, even at relatively alike altitude soils properties were found to be highly heterogeneous as a consequence of the heterogeneous substrates for soil formation including the varying hydrologic conditions, element redistribution on a landscape level as a result of the steep and uneven morphology, and potentially also due to drawbacks of the huge diversity of plant species. Further, soil of the Himalaya appears to have potential for significant carbon accumulation, especially in the high elevations (beyond 2500m). Hence, such areas need to be conserved under forest and natural vegetation to enhance C stocks and sequestration for mitigation of climate change.

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