Short Communication

Range Mgmt. & Agroforestry 41 (2) : 368-373, 2020

ISSN 0971-2070

Effect of altitude on soil properties of subalpine grasslands in Manang district of Nepal

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Received: 7th May, 2019 Accepted: 18th August, 2020

Abstract

Soil physical and chemical propersites play an important role in terrestrial carbon and nutrient cycling. During the growing seasons of 2017, the effect of altitude gradient on soil properties of grasslands were examined on the south-western slope of Manang district in Nepal. The changes of soil physical and chemical properties at a depth of 0-10 10-20 and 20-30 cm were examined in three altitudinal ranges (lower, middle and higher). For this study altitudes were selected, from 2500 to 4000 m. Soil bulk density was found in increasing order with increasing soil depth and soil properties such as soil pH, soil organic matter (SOM), nitrogen (N), available phosphorous (AP) and available potassium (AK) were found in decreasing order with increasing soil depth. Soil pH, soil organic matter, nitrogen and silt content (%) were significantly higher at lower altitude zone (2500 to 3000 m) than at upper and middle altitude zones. It was found that there was significant negative correlation between altitude with SOM, N and silt contents.

Keywords: Altitude, Correlation, Grassland, Soil properties, Subalpine

Grassland, covering major land area of earth, is one of the important resources which support the livelihoods of 1 billion people (Kemp *et al*., 2013). But these grasslands are under heavy grazing pressures and have deteriorated to a large extent (Roy *et al.,* 2019). The ecological restoration of degraded lands has a great significance in countries where their deterioration process covers large periods of time (Radu *et al.,* 2019). The mountain region, one of the most amazing physical structures of the earth, is famous for its unique landscape as well as its aesthetic biological and cultural values (Rawat, 1998). Of the total geographic area of 14.7 million hectares in Nepal, about 1.7 million hectares of land is occupied by grasslands, which are mostly covered by grasses, herbs and shrubs. In Nepal, grasslands are rich in biodiversity which provide diverse ecosystem services including production of animal protein for human consumption, carbon sequestration, non-timber forest products, and ecotourism (Thapa *et al*., 2016). Subalpine grasslands of Nepal are utilized for transhumance livestock system where livestock grazing include vertical movement from lower elevation to higher elevation in order to utilize maximum forage production during the summer months (McVeigh, 2004; Aryal *et al*., 2014; Aryal *et al*., 2015).

Altitude is an important factor in habitat diversity because it presents changes in the availability of resources, such as heat and water (Korner, 2000). In subalpine grasslands, altitude and slope degree play crucial role to alter local climate and soil properties (Hadjigeorgiou *et al.,* 2005). Previous studies recorded that the productivity in grassland mostly is affected by grassland management practices, soil properties, successional stages and climatic conditions (Papanastasis and Koukoulakis, 1988; Roukos *et al.,* 2010; Mountousis *et al*., 2011; Mpokos *et al.,* 2014; Ghosh and Mahanta, 2014; Karatassiou, 2016). However, little is known about the effect of altitude on soil properties and production in the global grassland. Even less studies are available to understand the effect of altitude zone on soil properties across subalpine mountain grasslands in Nepal. Therefore, the soil properties of the grasslands along the altitudinal gradient, focusing on a high-altitudinal range (2500-4000 m) were investigated at different locations in the Manang district of Nepal.

This study was conducted in Manang district (28° 27' to 28° 54' N latitude and 83°49' to 83°34' E longitude), the north-central part of Nepal. It lies in the trans-Himalayan region characterized by semi-arid cold desert condition like the Tibetan Plateau and receives little of the monsoon rain from the southeast and the southwest

(Aase and Vetaas, 2007; Måren *et al.,* 2015). The elevation of the study site ranged from 2500 to 4000 m. In Manang district, the parent material consisted of quartzites with layers of hematite, slates and limestone with clays and marble (Hagen, 1969). The total area of Manang district is 2246 km^2, of which 83.56% is occupied by mountain and hills, pastures cover 10.92% of total area, whereas 4.58% of the total area includes forest and shrubs (Bhatta, 2009).

During September 2017, 48 sites were selected for sampling. Sites were classified into three altitudinal zones based on altitude: lower (2500-3000 m), middle (3000-3500 m) and upper (3500-4000 m). Soil samples were collected at 15 sites in lower altitude zone, 17 sites in middle altitude zone and 16 sites in upper altitude zone. Soil samples were collected from top of the surface layer to the depth of 30 cm at 10 cm intervals (0 - 10 cm, 10-20 cm and 20-30 cm; Singh *et al.,* 2018). Collected soil samples were taken to the laboratory. Plant roots and residues were removed from the soil samples and then they were air-dried and sieved through a 2 mm soil sieve to measure the physical and chemical characteristics of the soil.

Physiochemical parameters were analysed as per the standard procedures. The pH- determination (1:2.5 w/vol) was done by using the digital pH meter (Davis and Freitas, 1970) and organic matter was determined by the Walkley-Black method (Nelson and Sommers, 1996). Nitrogen (N) content was determined by following Kjeldahl method (Bremner, 1960). Available phosphorus (AP) content (ppm) was determined by using Bray-P1 method (Bray and Kurtz 1945). Available potassium (AK) content (ppm) was determined by flame photometer method (1986). Additionally, soil bulk density was estimated for soil cores of known volume (4.8 cm diameter x 10 cm height) at 0-10 and 20-30 cm depth per site by using core sampling method (Blake and Hartge, 1986) and oven dried at 105°C to constant weight for moisture correction. For sites with significant differences, the least significant difference (LSD) test was conducted at $P < 0.05$.To assess how each soil properties responded to elevation, the relationship between altitude and soil properties was further analysed through Spearman correlation analysis. All statistical analysis was performed using software package of SPSS 16.0 (SPSS Inc., Chicago, IL, USA).

There was gradual increase in soil bulk density (BD) with increasing soil depth in three different altitude ranges. The minimum BD was found at top level of the soil, which indicated that soil was suitable for vegetation growth compared to other soil depth. Soil properties such as soil pH, SOM%, N%, AP and AK contents were gradually decreased with increasing soil depth (Table 1). This study also showed that soil pH and soil nutrients (SOM%, N%, AP and AK) were high at top soil due to presence of vegetation compared to other two soil depth which had no vegetation except root of the vegetation. The result was in conformity with the previous study (Bidgoli *et al.*, 2019) who found that physical and chemical properties (clay, silt, gravel, EC, pH, OM, P and K) of the soil at 0-30 and 30-60 cm were different at two depths of soil.

Table 1. Soil properties of three different altitude range at different soil depth

Soil depth (cm)	BD (gm/cm^3)	pH	SOM (%)	N (%)	Available K (ppm)	Available P (ppm)
Lower range						
0-10	1.12	7.22	3.75	0.47	102	4.12
10-20	1.19	6.93	3.52	0.40	95	4.07
20-30	1.38	6.81	2.72	0.36	84	3.83
Mean	1.23	6.98	3.33	0.41	93.66	4.01
Middle range						
0-10	0.98	6.92	2.36	0.21	73	4.09
10-20	1.15	6.87	1.93	0.16	58	3.84
20-30	1.20	6.73	1.67	0.08	45	3.63
Mean	1.11	6.84	1.98	0.15	58.66	3.85
Upper range						
0-10	1.24	6.16	1.96	0.21	96	3.23
10-20	1.19	6.05	1.81	0.17	87	3.17
20-30	1.17	5.7	1.7	0.10	79	3.25
Mean	1.2	5.97	1.82	0.16	87.33	3.21

Bulk density was comparatively higher with mean value of 1.23 g cm^{-3} in the lower zone than the two other zones. While with respect to soil texture, sand content (%) was higher in the upper zone followed by middle and lower zones. But the values on sand content (%) was not significantly different in the three zones (P >0.05). Silt content (%) was found significantly higher in the lower zone where as it was comparable between middle and upper zones. There was no significant difference in clay content (%) of all three zones, however, the lower zone had the maximum clay content (%) followed by middle and upper zones, respectively.

Soil pH is one of the important factors that regulates the floristic diversity and composition of grasslands (Critchley *et al*., 2002). The overall mean soil pH values ranged from 5.9 at higher altitude which was significantly lower than the pH value at middle and lower altitude (Table 2). Thus soil pH had reverse relationship with elevation. This finding was found consistent with the findings of earlier studies carried out by (Oztas *et al*., 2003; Yimer *et al.,* 2006; Oyonarte *et al*., 2008) which showed soil pH decreases with increase in altitude.

Soil organic matter was found significantly highest in the lower zone than the middle and upper zones. According to Holzmann and Haselwandter (1988), soil organic matter generally limits the supply of soil nutrients, resulting less production in mountainous region. In the present study, soil organic matter content was significantly higher at lower altitude compared to middle and upper altitude zones and there was significant negative correlation between SOM content and elevation. Among the three zones, the value of available phosphorous and potassium were maximum at the lower zone compared to middle and lower zone, however there was no significant difference of available phosphorous and potassium contents in all three zones.

Nitrogen (N) is an essential nutrient which controls plant growth in terrestrial ecosystems (Chapin *et al*., 1986; Bhandari *et al*., 2016). Soil nitrogen was significantly higher in lower zone followed by middle and upper zones, respectively. Soil nitrogen is the important mineral nutrient that plants requires in adequate quantity (Chapin *et al.,* 1987), otherwise lack of nitrogen limits plant growth in natural ecosystems because of its major role in the photosynthetic process (Bowman *et al*., 1993).

The Spearman correlation analysis indicated that altitude was negatively related with the SOM%, nitrogen % and silt % and the correlation coefficients were -0.342, -0.340 and -0.300, respectively (Table 3). In higher altitudinal zones, due to low temperature the microbes are less active in the topsoil, which in turn reduces the microbial decomposition of soil organic matter (Wang *et al*., 2007). The erosion in higher altitude usually causes loss of soil organic matter and nitrogen which results in a deterioration of soil physical condition leading to limitation in production (Greer *et al*., 1996). This finding was in line with the previous study which showed that soil organic matter decreased from lower elevation to

Table 2. Soil properties in relation to altitudinal zones

Soil properties	Altitude		
	Lower (2500-3000 m)	Middle (3000-3500 m)	Upper (3500-4000 m)
BD (g/cm^3)	1.23± 0.07^a	1.11± 0.06^a	1.20±0.08^a
Sand (%)	65.37± 1.72^a	68.34±2.11^a	70.66±2.59^a
Silt (%)	19.14± 1.51^a	12.59± 1.61^b	11.83±2.29^b
Clay (%)	20±4.87^a	19.06±0.71^a	17.5±0.63^a
Soil pH	6.99±0.15^a	6.84±0.21^a	5.97±1.24^b
SOM%	3.33±0.23^a	1.98±0.26^b	1.82±0.22^b
N%	0.41±0.09^a	0.15± 0.02^b	0.16±0.02^b
Available P (ppm)	4.02 ± 0.82^a	3.85±1.33^a	3.22± 0.68^a
Available K (ppm)	93.70±12.87^a	58.70±8.94^a	87.37±24.39^a
Soil type	SL	SCL	SL

Values (mean ± SE) bearing different superscript (a, b) in a same row differ significantly (P<0.05); SL: Sandy loam, L: Loam. SCL: Sandy clay loam

Table 3. Coefficient of correlation between altitude and soil properties

	Soil pH	SOM (%)	N (%)	AK (ppm)	AP (ppm)	Sand (%)	Silt (%)	Clay (%)	BD (g/cm^3)
Altitude	-0.213	-0.342*	-0.340*	-0.092	-0.198	0.199	-0.300*	-0.022	-0.105

*Correlation significant (P<0.05)

higher elevation (ChatzitheodoRidis *et al*., 2011). The negative relationship between altitude and nitrogen% was also in agreement with the finding of earlier study (Zhang *et al.,* 2012), where soil N mineralization and nitrification rates were decreased with the altitude. Similarly silt% was found significantly higher in lower altitude zone compared to middle and higher altitude zones and there was negative correlation between the silt% and altitude. Earlier studies which also showed that silt content (%) decreased along the altitude at cold desert of Leh-Ladakh, India (Charan *et al.,* 2013).

Study revealed that in subalpine mountainous grassland, the altitudinal gradient affected the soil properties such as soil pH, SOM, N and silt contents. As altitude increased these soil properties decreased in subalpine mountainous environment. Because of negative correlation of altitude with soil pH, SOM, N and silt contents, the level of soil nutrients need to be maintained in middle and upper altitude zones by conserving the soil from erosion and landslides.

Acknowledgement
We thank the Program for Academician Workstation in Guiyang University NO. NO20195605, Guizhou Provinceÿthe Regional First Class Discipline Construction of Guizhou Province to GYU (No. [2017]85), Provincial Key and Special Subject of Guizhou Province–Ecology (No. ZDXK[2015]11), and the Training Project for High-Level Innovative Talents in Guizhou Province (No. 2016 [4020]) for financial supports.

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