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Physico-Chemical Characteristics of Soil Along an Altitudinal Gradients at Southern aspect of Shivapuri Nagarjun National Park, Central Nepal

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Abstract

This study accessed the variation in physico-chemical properties of soil from the Shivapuri Nagarjun National Park, central Nepal with respect to elevation gradient. Field visits were conducted during pre-monsoon and post-monsoon season. Soil samples were collected at every 100 m increase in elevation at the 15 cm depth from 1600 m to 2732 m (lower range is dominated by pine forest while upper range is by broad leaf forest with dense canopy) and packed in airtight polythene bag. Different parameters such as pH, soil moisture, organic matter, nitrogen, potassium, phosphorus and water holding capacity were analysed in the lab by using standard protocols. Significant variation in soil properties at different altitudinal range was observed. Soil pH had negative relationship with increasing altitude but soil nitrogen, organic matter, soil moisture and water holding capacity was found to be increasing with increasing altitude. But in case of potassium, high concentration was observed in the middle altitudinal range while phosphorus content was stable during pre-monsoon and higher concentration at middle range during post monsoon.

Keywords: Soil, physico-chemical properties, elevation gradient, Shivapuri Nagarjun National Park, Nepal.

Introduction

Composition and properties of soil is controlled by different environmental factors like slope, aspect, climate, landscape, microclimate, topography and vegetation[1,2]. Soil is very important factor in determining the vegetation. Variation in surface soil characteristics leads to changes in vegetation distribution. The edaphic factors have the significant influence for vegetation heterogeneity in the natural forest[3]. The physiochemical properties of natural forest soils varied in different places. Vegetation structure, physical topography, climate as well as microbial activities have important effect on physical and chemical properties of soil which ultimately have significant influence on the composition of plant community structure and natural regeneration of plants[4]. As the plant tissues are the main source of soil organic matter (OM), vegetation plays an important role in soil formation[5]. Similarly; pH, texture, nutrient availability and water-holding capacity (WHC) also depends on the vegetation type[6]. Nutrient supply differs broadly in between different ecosystems[7]. The soil organic matter and water holding capacity are directly proportional with increasing elevation whereas soil pH decreases with increasing elevation[8]. The higher concentration of organic carbon was reported in broad leaf forest in comparison with conifer forest [9]. Soil properties were found to be changing with different disturbances, higher soil pH concentration in disturbed forest[10].

Few works have been done on soil physiochemical characteristics at different elevations in the mid-hills of Nepal. Thus, we carried out the study in an undisturbed natural forest to document the physiochemical properties of soil along elevation gradient during pre-monsoon and post-monsoon in the southern aspect of Shivapuri Nagarjun National Park, central Nepal.

Study area: Shivapuri Nagarjun National Park (27°45' to 27°52' N and 85°15' to 85° 30' E; altitude ranging from 1366m to 2732 masl and area 159 km^2) lies at about 12 km north of Kathmandu valley. Protection of the area as watershed began in 1975 under Shivapuri Watershed Development Board. Later on in 1985, the area was established as a Wildlife Reserve under Shivapuri Watershed Management and Fuelwood Plantation Project. In 1992, as a follow-up program, 'Shivapuri Integrated Watershed Development Project was initiated. In 2002, it was gazetted as the ninth national park of Nepal. It is the newest national park of Nepal which lies nearest to the capital city. The park was extended by including Nagarjun Forest Reserve covering 15 km^2 in 2009. The area is source of high quality drinking water providing about 1 million cubic litre of water per day[11]. The national park covers 23 village development committees (VDCs) of Kathmandu, Nuwakot and Sindhupalchowk districts.

Soils of the study area contain metamorphic rocks such as phyllite, limestone and dolomite, gneiss and ingratiate [12] which are loamy on the northern aspect and sandy on the southern aspect. Due to the dense vegetation covers, in most of the park area, the run off rate is relatively low and the nutrient content in the soils is high. In contrast, in the degraded forest areas the rate of run-off and soil erosion is relatively high[12]. The soil of Shivapuri Nagarjun National Park is under different categories as given below: overused soil (1122ha), soil-needing treatment (10,090 ha), soil used within capability (6,491 ha), serious used soil (9491 ha) and under use soil (2,350 ha)[13]. Since the park is mountainous, it has four lands form types: alluvial plains and fans (1,525ha - about 7.2% of the total area), ancient lakes and rivers terrace (1520 ha, 7.2%), moderately to steeply sloping mountainous terrain (13,440 ha, 63.4%) and steeply to very steeply sloping mountainous terrain (4718 ha, 22.2%)[14]. The region has seasonal climate with rainy (monsoon) season (June to September), cool dry winter (October to February) and hot dry summer (March to May). Land Resource Mapping project[14] classified forest of this National Park into two types: deciduous mixed broad-leaved forest and coniferous chir pine forest. About 50% of the park area is covered by forest with the prominence of subtropical and temperate type of vegetation. Figure 1 shows the location of three different sampling sites.

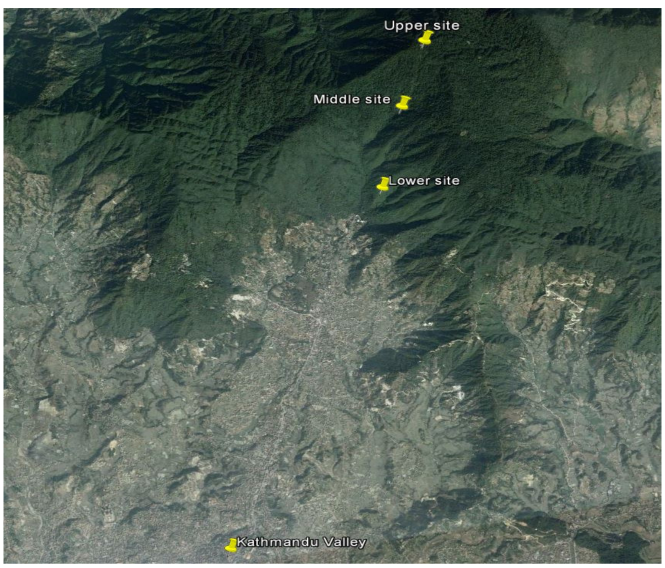

Figure-1
Sampling sites location (Google earth)

Methodology

Soil samples were collected from three different altitudinal range i.e. lower (1600m-1800m), middle (1900m-2300m) and upper (2400m – 2732m). Lower elevations were dominated by pine forest while middle and upper lower elevations were dominated by broad leaf forest. Samples were taken at every 100m increment of elevation at the 15 cm depth and packed in airtight polythene bag. Soil moisture (on dry weight basis) and water holding capacity and pH, organic matter (OM), nitrogen N), potassium (K) and phosphorus (P) were determined at Soil Test and Service Section, Hariharbhawan, Lalitpur by using following laboratory methods.

Soil moisture (SM): It was measured by using the formula given by Zobel method [15]

$$\text{Soil moisture (\%)} = \frac{\text{Fresh weight - Dry weight}}{\text{Dry weight of soil}} \times 100$$

Water holding Capacity (WHC): It was also measured by using the formula given by Zobel method [15]

$$\text{WHC (\%)} = \frac{\text{Volume of water retained by soil}}{\text{Dry weight of soil}} \times 100$$

Soil pH: Portable pH meter measured it.

Organic matter (OM): It was determined using the formula by Walkley-Black method [16]

$$\text{OM (\%)} = \frac{(B - S)N}{\text{Weight of Soil}} \times 0.067 \times 100$$

Where, B = volume of FAS used up for blank titration, S = volume of FAS used up for sample titration, N = Normality of FAS from blank titration, FAS = 0.5 N ferrous ammonium sulphate.

Nitrogen (N): Nitrogen content in the soil was determined by Kjeldahl method [17]

$$\text{Nitrogen (\%)} = \frac{T - B \times N \times 100}{S}$$

Where, T = Sample titration, ml. of standard acid, B = Blank titration, ml. Of standard acid, N = Normality acid, S = Sample weight.

Phosphorus (P): It was estimated by following Olsen method [18]
Phosphorus (kg/ha) = F x R,

where, F = Coefficient factor calculated from blank solution,
R = Reading in spectrophotometer

Potassium (K): It was measured by flame photometer following Puffeles and Nessim method [19]

$$\text{Potassium (kg/ha)} = \frac{R\ 20}{7} \times 1.2 \times 2\,,$$

Where: R = Reading in photometer

Analysis of Correlation Coefficient: The degree of relationship between two sets of figures is measured as correlation coefficient (r) [20]

$$r = \frac{\sum xy - \frac{\sum x - \sum y}{n}}{\sqrt{\left[\sum x^2 - \frac{\left(\sum x\right)^2}{n}\right]\left[\sum y^2 - \frac{\left(\sum y\right)^2}{n}\right]}}$$

where, r = correlation coefficient, ∑ = sum, x = independent variable, y = dependent variable, n = no. of variables.

Results and Discussion

Nitrogen (N): Average nitrogen content in the soil range from to 0.13% in lower elevation to 0.39% in upper elevation in rainy season. It was high in summer, ranging between 0.18% (Lower elevation) and 0.62% (upper elevation). The soil nitrogen content increased with increasing altitude. Soil nitrogen content differed significantly in three forests in both the seasons. It increased with the increasing altitude. The nitrogen content in rainy season ranged from 0.13% to 0.39% while in dry season it ranged from 0.18% to 0.62%. High nitrogen content at high altitude may be due to wet condition, which enhanced the activity of nitrogen fixing bacteria. At low altitude soil was drier than at high altitude. The lower value of nitrogen in the rainy season was due to the loss by erosion and leaching. Nitrate is highly soluble in water and thus lost during rainy season. Moreover, rainy season being the growing period, much of the total uptake and incorporation of minerals is completed before rapid increase in mass begins[21]. Higher nitrogen content in dry season is due to accumulation of nitrogen by biological fixation, lower rate of leaching and enhanced activity of nitrogen-fixing bacteria. Similar trend of nitrogen content was also reported for another part of the country[22].

Phosphorus (P): Phosphorus content of the soil was 29.9 kg/ha in all sites during rainy season. It increased in summer; soil Phosphorus was highest at middle elevation (127.02 kg/ha) and lowest at lower elevation (55.04% kg/ha). Phosphorus content in the rainy season was equal in all three sites i.e. 29.9 kg/ha. But it increased in the dry season and ranged from 55.04 - 127.02kg/ha. There was no impact of altitude on the phosphorus content. Highest value was recorded for middle elevation i.e. 127.02 kg/ha. The low amount of phosphorus in rainy season may be attributed to the rapid utilization by large trees as well as regenerating plants. The low value of phosphorus was also due to the formation of iron and aluminum phosphate[23]. The estimated value was close as reported in Udayapur of Nepal[24].

Potassium (K): Potassium was higher in summer than in rainy season. It ranged between 126.59 kg/ha (upper elevation) to 243.67 kg/ha (middle elevation) in rainy season while in summer it ranged 382.15 kg/ha (upper elevation) to 853.17 kg/ha (middle elevation). The middle elevation had highest soil potassium in both seasons. Potassium content was 126.59 kg/ha to 243.67 kg/ha in the rainy season. This increased in the dry season and ranged between 382.15 kg/ha to 853.17 kg/ha. In both seasons, middle elevation had the highest potassium content. Similar pattern was also observed for phosphorus. Richards and Wadleigh[25] showed the relationship between phosphorus and potassium. As the drying of soil result in fixation of both potassium and phosphorus, so they become unavailable. As a result plants in dry soil tend to be low in both phosphorus and potassium, which retard the plant growth. This value had the similar type of trend as in Udayapur [24]. This value was close to that in nearby Gokarna forest[26]. Higher value in the dry season may be due to the lower number of annual plants; so the accumulation of potassium in the form of biomass was highest. Figure 2 shows the distribution of N, P and K in different seasons at different sites.

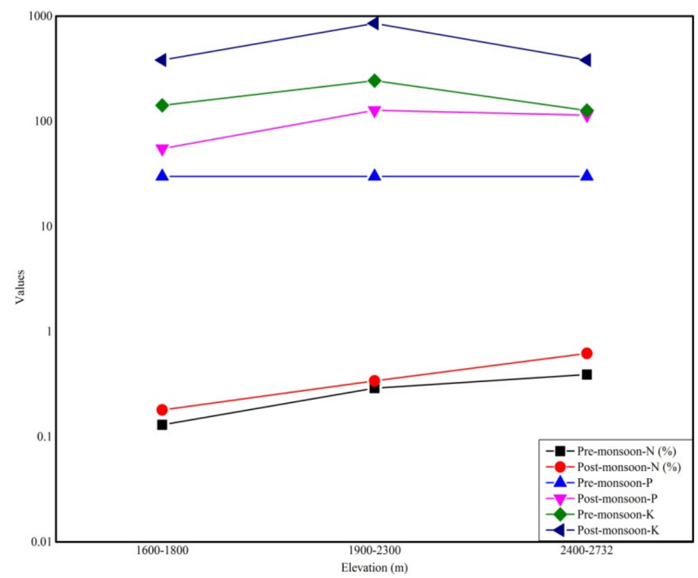

Figure-2
Distributions of Nitrogen (N), Phosphorus (P) and Potassium (K)

Soil pH: The soil in the Shivapuri forest was found to be acidic. pH value ranged from 3.6 - 4.8 in rainy season and 4.2 - 5.2 in summer. In both seasons, lower elevation had the highest pH value which decreased with altitude. The soil of study area was acidic and soil pH decreased with increasing altitude during both seasons. It was higher in dry season than in rainy. It may be due to high microbial activities in rainy season which produced CO_2, humic acid, fulvic acids and other inorganic acids. This value of pH was close to that of Nagarkot hill[27].

Organic Matter (OM): Soil organic matter increased with altitude. The values were lowest at lower elevation and highest at upper elevation. It was high in summer at all sites. The OM ranged from 2.79% to 7.92% in rainy season, and 3.54% to 12.36% in summer. Organic matter (OM) is the chief source of minerals return to soil and is contributed by dead bodies of plants and animals as well as micro and macro-organisms living in the soil. The values ranged from 2.79% to 7.92% in rainy season and 3.54% to 12.36% in dry season. In both seasons, OM increased with the altitude. The average OM content was high in all altitudinal range in the dry season. Value from our study was found to be very close with previous study[28] in Shivapuri.

Soil moisture (SM): The soil moisture was highest in the rainy season (23.81% to 26.08 %); and it decreased in summer (6.04% to 17.38%). Soil moisture (SM) showed direct relation with precipitation, as it was high in rainy season and low in dry season with the values ranging from 23.8% to 26.08% and 6.04% to 17.38% in respective seasons. It also showed direct relationship with altitude. Similar types of results were also reported in another part of Nepal[22]. More exposed area in lower elevation might have contributed for lower value of soil moisture than in upper elevation. It may also be due to more ground cover with large trees in higher altitude, which block the direct sunlight and continuous rainfall.

Water holding capacity (WHC): The water holding of soil increased with altitude in the both the seasons. It was higher in the rainy season than in summer. The highest WHC (75%) was recorded at upper elevation in rainy season; and the lowest (58%) at lower elevation in dry season. Water holding capacity of the soil is another important factor for good regeneration of trees and saplings. Average water holding capacity ranged from 58.55 to 75%. There was slight variation in water holding capacity along altitude i.e. as altitude increased WHC also increased and the value was slight higher in rainy season. It may be due to presence of high amount of litter during rainy season and in high altitude, the soil texture is most important factor for determining the WHC. Soil sample with higher amount of sand and silt particles has the lower WHC but with higher amount of clay favors higher WHC. WHC value is also higher in the regenerating areas due to high litter content. Figure 3 shows the distribution of soil pH, organic matter, soil moisture and water holding capacity at different elevation during different seasons.

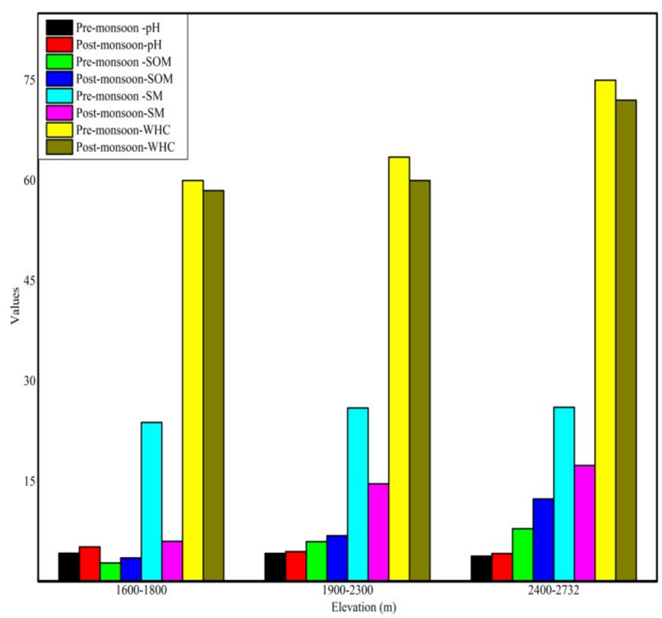

Figure-3
Soil pH, organic matter, moisture and water holding capacity at different elevations

Correlation Coefficient: Regarding correlation coefficient of soil parameter; pH was positively correlated (r = 0.44) only with potassium, whereas there was negative correlation between pH and other parameters in lower elevation. OM was negatively correlated with pH (r = -0.239) and WHC (r = -0.028) in Lower elevation, with SM (r = -0.685) in middle elevation and with K (r = -0.236) in middle elevation where as positive correlation with other parameters. N was negatively correlated with pH (r = -0.245) and with WHC (r = -0.25) in upper elevation and positive correlation with other parameters. Potassium was highly positively correlated with pH in all sites. Phosphorus was negatively correlated with in Lower elevation and II and strongly positively correlated (r = 0.647) in upper elevation. WHC was not related with Phosphorus in middle elevation and upper but strongly positively correlated (r = 0.707) in Lower elevation (table 1). Regarding the correlation coefficient between the physio-chemical characteristics of soil samples; pH was negatively correlated with all parameters except potassium in lower elevation, while positively correlated with all parameters except SM and WHC in upper elevation. Such type of negative correlation of pH with OM (r = -0.311) and N (r = -0.422) have been reported earlier[24] in tropical sal forest in eastern Nepal. Phosphorus and Potassium were positively correlated with all other than SM and P was found to be negative correlated with K in middle elevation. OM and N were negatively correlated with WHC, SM and K in lower, middle and upper elevation respectively. P was positively correlated with all components other than pH and SM. Potassium was positively correlated with all parameters except SM and WHC. SM was negatively correlated with all parameters. WHC was positively correlated except with K and SM. In middle elevation zone, pH has similar type of relation that in lower elevation. OM and N were negatively correlated only with K. P was negatively correlated with SM only and was negatively correlated with all parameters except with pH and P as found in China[29]. The variation in the correlation coefficient values in different sites may be due to the variation in plant community structure.

In the lower altitude the plant community was dominated by *Pinus roxburghii*[30]. But the pH value of the soil decreased with altitude i.e. soil becomes more acidic where *Rhododendron arboreum* which flourish in acidic soil made dominancy. This may also be due to the higher value of soil moisture, OM and N in higher altitude. The higher value of Phosphorus and potassium in middle elevation prefer the better growth of *Quercus glauca, Castanopsis tribuloides* etc. This higher quantity of P and K may be due to the crowded canopy of vegetation. Middle elevation had highest density of trees[30] may be due to presence of suitable amount of soil nutrients. The higher amount of potassium in middle elevation was available due to the presence of higher number of annual plants[30] where potassium was accumulated from biomass. The lowest value of SM in lower elevation was due to lesser tree crown cover and highest in middle elevation was due to higher tree crown cover which may reduce the evaporation rate of soil. In all sites N content was lower in rainy season because of higher density of herbaceous plants in rainy season[30].

Table-1
Correlation coefficient between different parameters

1600-1800m	**pH**	**OM**	**N**	**P**	**K**	**SM**	**WHC**
pH	1	-	-	-	-	-	-
OM	-0.24	1	-	-	-	-	-
N	-0.25	1	1	-	-	-	-
P	-0.58	0.52	0.52	1	-	-	-
K	0.44	0.55	0.54	0.42	1	-	-
SM	-0.40	0.02	0.02	-0.20	-0.44	1	-
WHC	-0.23	-0.03	-0.03	0.71	0.34	-0.21	1
1900-2300m	pH	OM	N	P	K	SM	WHC
pH	1	-	-	-	-	-	-
OM	0.53	1	-	-	-	-	-
N	0.53	1	1	-	-	-	-
P	-0.20	0.53	0.53	1	-	-	-
K	0.33	0.53	0.53	-0.60	1	-	-
SM	-0.07	-0.69	-0.69	-0.74	-0.35	1	-
WHC	0.09	0.36	0.36	0	-0.08	-0.38	1
2400-2732m	pH	OM	N	P	K	SM	WHC
pH	1	-	-	-	-	-	-
OM	0.04	1	-	-	-	-	-
N	0.02	1	1	-	-	-	-
P	0.65	0.52	0.50	1	-	-	-
K	0.91	-0.24	-0.25	0.27	1	-	-
SM	-0.41	0.54	0.56	-0.41	-0.29	1	-
WHC	-0.76	0.39	0.40	0	-0.96	0.19	1

Conclusion

Soil samples were taken during two seasons (Pre-monsoon and Post-monsoon) at 3 different elevations. Soil analysis showed that the soil of forest was acidic (pH 3.82-5.2). The pH was lowest in rainy season. Nitrogen content also increased with altitude and was found highest during dry season. Same was the case with Phosphorus as well. Potassium content was also higher in dry season and middle range of altitude soil moisture was directly related to precipitation i.e. higher in rainy season and lower in dry season. Water holding capacity was also increased with altitude and decreased during dry season.

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