Altitudinal Variation in Soil physico-chemical properties of a Western Himalayan Forest , Uttarakhand, India

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Abstract: The physico-chemical properties of soil vary with the variation in the topographic features, climatic conditions and forest types. In any forest ecosystem, both vegetation and soil influence each other through nutrient cycles. The altitudinal variation in soil physico-chemical properties was analyzed in a temperate forest (Radi forest) of Upper Yamuna Forest Division in Uttarkashi district of Uttarakhand (Western Himalaya, India). A total of three forest sites were selected at different altitudes (the lower, middle, and upper) to collect composite soil samples from each site covering 0–10 cm, 11–20 cm and 21–30 cm depths. The textural class of the soils was sandy loam. The colour of the soil samples varied from brown to very dark brown. The water holding capacity ($r = 0.994$), soil organic carbon ($r = 0.967$), organic matter ($r = 0.966$), nitrogen ($r = 0.993$), phosphorus ($r = 0.982$) and potassium content ($r = 0.994$) had positive correlation with altitude whereas negative correlation was observed between altitude and soil pH ($r = -0.983$) in the study. The present study concludes that soil physico-chemical properties in temperate forests of Uttarakhand Himalaya vary significantly with variation in altitude.

Keywords: Altitudinal gradient; Composite soil sample; Physico-chemical properties; Soil analysis; Temperate forest.

Introduction

Soil is one of the basic natural resources on which all terrestrial life forms co-exist. It plays a vital role in maintaining the productivity and sustainability of forest ecosystems (Tiwari 2005). Soil and forest together constitute an important support system of our life. The organic matter and nutrients are of basic importance in the study of soil as they are responsible for its various physical and chemical properties and ultimately influence the vegetation (Jha *et al* 1984). The nature of soil profile and nutrient cycling between the soils and plants are the essential dimensions to determine the quality of a forest. The growth and reproduction of forests cannot be understood without the knowledge of soil (Miller and Donahue 1990). Forest soil influences many forest attributes like composition of the forests, rate of tree growth, efficacy of natural reproduction, etc. (Bhatnagar 1965). Also, the underground life of a forest is the key to an adequate understanding of its above surface life. Hence, the knowledge of soils properties is essential to understand the forest community dynamics and plan management strategies.

In the present study, we have investigated the soil physico-chemical properties (texture, colour, moisture content, water holding capacity, pH, organic carbon, organic matter, total nitrogen, available phosphorus and potassium) across the elevation gradient in a temperate forest (Radi forest) of Upper Yamuna Forest Division in Uttarkashi district of Uttarakhand, Western Himalaya, India.

Materials and methods

Study area

The present study was carried out to analyse soil physico-chemical properties at three different altitudes in the Radi forest (30°46′16.6″N to 30°46′42.5″N and 78°14′21.6″E to 78°15′45″E) of Upper Yamuna Forest Division in district Uttarkashi, Uttarakhand (Fig. 1). This forest has thick tree cover of *Quercus leucotrichophora* in association with *Rhododendron arboreum*, *Lyonia ovalifolia*, *Cedrus deodara*, *Quercus floribunda*, *Pinus wallichiana*, etc. (Fig. 2). Three forest sites were selected and based on altitude were classified as lower (R1), middle (R2), and upper (R3) (Table 1). The texture of the soil was predominantly sandy loam, and the soil was acidic. The area has three major seasons, viz., cold and dry winter (December to February), warm and dry summer (April to mid-June) and rainy (mid-June to September), whereas spring (February to March) and autumn (October to November) are transition periods. Snowfall occurs during January and February.

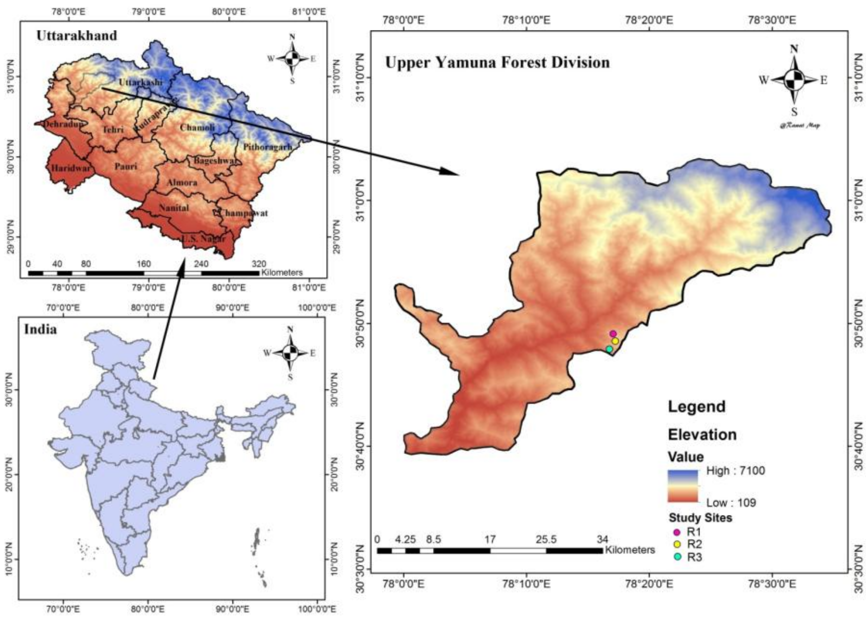

Figure 1: Map showing the location of study area and the sites (R1, R2 and R3).

Figure 2: a. Radi forest in Uttarkashi, **b, c.** Broad leaved forest stands in Radi forest, and **d.** Collection of soil samples during the field visit.

Table 1: Description of the study sites in Radi forest of Upper Yamuna Forest Division (Uttarkashi, Uttarakhand).

S. No.	Site (code)	Altitude (m asl)	Latitude	Longitude	Aspect*
1	Lower (R1)	1800	30°46′42.5″N	78°15′43.5″E	N
2	Middle (R2)	2100	30°46′36″N	78°15′45″E	NW
3	Upper (R3)	2400	30°46′16.6″N	78°14′21.6″E	NE

**N=North, NW=Northwest, NE=North East.*

Methodology

The soil samples were collected from each forest at three depths, viz. 0–10 cm, 11–20 cm, and 21–30 cm. The composite soil samples were prepared by mixing five samples of each depth taken randomly from different places in the forest (Fig. 2). The samples were tightly packed in plastic bags with field details and brought to the laboratory for further analysis. The physical properties like moisture content, water holding capacity, colour and texture were analyzed in the Botany Research Laboratory at Department of Botany and

Microbiology, HNB Garhwal University, Srinagar (Garhwal). The chemical properties like pH, organic carbon, organic matter, total nitrogen, available phosphorus and potassium were analyzed in the Soil Laboratory of Forest Ecology and Climate Change Division, Forest Research Institute, Dehradun.

Physical properties

The soil texture was determined using sieves of different pore sizes following Pandeya *et al*. (1968), and the USDA textural triangle was used to identify the texture classes. The soil colour was determined with the help of Munsell soil colour chart. Misra (1968) was followed to determine the water holding capacity of the soil samples.

$$Water\ Holding\ Capacity\ (WHC) = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

where W_1=Weight of empty crucible; W_2= Weight of crucible with wet (saturated soil); W_3=Weight of crucible with dry soil.

The method suggested by Miller and Donahue (1990) was used to determine the per cent of moisture content in soil.

$$Moisture\ Content\ (\%) = \frac{Weight\ of\ moist\ soil - Weight\ of\ oven\ dry\ soil}{Weight\ of\ oven\ dry\ soil} \times 100$$

Chemical properties

The digital pH meter was used to measure the soil pH. The rapid titration method of Walkley (1947) was used to calculate the per cent of soil organic carbon present in the soils. The soil organic matter (%) was calculated using the factor of 1.724 of organic carbon (%). Olsen *et al*. (1954) was followed to calculate the available phosphorus. Ammonium acetate method of Morwin and Peach (1951) was used to extract potassium, and then estimation was done by using flame photometer. Estimation of total nitrogen was done following Kjeldhal procedure given by Bremner and Mulvaney (1983).

Results

In the present study, hue was 7.5YR for the soil samples, value ranged from 2.5 to 4, and chroma varied between 2 and 4 (Table 2). The soil colour ranged from brown to very dark brown. The texture of soils was sandy loam throughout the study sites (Table 3). The values for water holding capacity (WHC) decreased with increase in soil depth at all the sites. The WHC (r = 0.994) was found to be positively correlated with the altitude (Fig. 3). The soil moisture was negatively correlated with the altitude.

Table 2: Variation in soil colour along the altitudinal gradient in the study area.

S. No.	Site	Hue	Value/Chroma	Colour
1	R1	7.5YR	4/4	Brown
2	R2	7.5YR	3/3	Dark brown
3	R3	7.5YR	2.5/2	Very dark brown

Table 3: Physical properties of soil along different altitudes and depths.

Site	Depth (cm)	WHC (%)	MC (%)	Sand (%)	Silt (%)	Clay (%)	Textural class
R1	0-10	59.80	19.27	64.56	30.35	5.09	Sandy loam
	11-20	53.42	21.13	64.97	29.15	5.88	
	21-30	49.13	23.08	64.51	29.46	6.03	
	Mean±SD	**54.12±5.37**	**21.16±1.91**	**64.68±0.25**	**29.65±0.62**	**5.67±0.51**	
R2	0-10	62.79	17.14	50.46	40.25	9.25	Sandy loam
	11-20	58.64	16.56	51.09	39.83	9.08	
	21-30	54.07	18.23	51.71	40.16	8.13	
	Mean±SD	**58.50±4.36**	**17.31±0.85**	**51.09±0.63**	**40.21±0.06**	**8.82±0.60**	
R3	0-10	65.89	13.45	64.76	26.53	8.71	Sandy loam
	11-20	61.56	15.31	65.21	26.91	7.88	
	21-30	57.04	17.05	65.91	27.05	7.04	
	Mean±SD	**61.50±4.43**	**15.27±1.80**	**65.29±0.58**	**26.83±0.27**	**7.88±0.84**	

Abbreviations used: *WHC=Water holding capacity; MC=Moisture content.*

The values for total nitrogen (N), available phosphorus (P), available potassium (K), organic carbon (OC), soil organic matter (SOM) and pH across the study sites ranged from 0.27±0.04 to 0.37±0.04 %, 27.56±2.69 to 31.98±3.88 kg ha^{-1}, 127.31±27.44 to 198.03±36.03 kg ha^{-1}, 1.32±0.39 to 2.57±0.52 %, 2.38±0.66 to 4.44±0.90 % and 5.21±31 to 6.12±0.30 respectively (Table 4). The soil of all the forest sites was acidic. The OC (r = 0.967) and SOM (r = 0.966) were positively correlated with altitude and had a negative relationship with soil depth. In contrast, the pH (r = -0.983) showed a negative correlation with altitude and had a positive relationship with depth. The total N (r = 0.993) and available K (r = 0.994) were positively correlated with altitude and had a negative relationship with depth. The available P (r = 0.982) showed a positive correlation with altitude and did not show any fixed trend with depth (Fig. 3).

Table 4: Chemical properties of soil along different altitudes.

Site	Depth (cm)	pH	OC (%)	SOM (%)	N (%)	P (kg ha^{-1})	K (kg ha^{-1})
R1	0-10	5.81	1.73	2.98	0.31	30.11	154.56
	11-20	6.14	1.27	2.19	0.27	27.81	127.69
	21-30	6.41	0.96	1.66	0.24	24.75	99.68
	Mean±SD	**6.12±0.30**	**1.32±0.39**	**2.28±0.66**	**0.27±0.04**	**27.56±2.69**	**127.31±27.44**
R2	0-10	5.40	2.16	3.72	0.36	25.26	224.12
	11-20	5.71	1.65	2.84	0.33	28.83	157.44
	21-30	6.13	1.17	2.02	0.29	33.03	126.36
	Mean±SD	**5.75±0.37**	**1.66±0.50**	**2.86±0.85**	**0.33±0.04**	**29.04±3.89**	**169.31±49.95**
R3	0-10	4.90	3.04	5.24	0.41	35.46	235.03
	11-20	5.22	2.67	4.60	0.37	32.68	196.01
	21-30	5.51	2.01	3.47	0.34	27.80	163.05
	Mean±SD	**5.21±0.31**	**2.57±0.52**	**4.44±0.90**	**0.37±0.04**	**31.98±3.88**	**198.03±36.03**

Abbreviations used: *OC = Organic carbon; SOM = Soil organic matter; N = Nitrogen; K = Potassium; P = Phosphorus.*

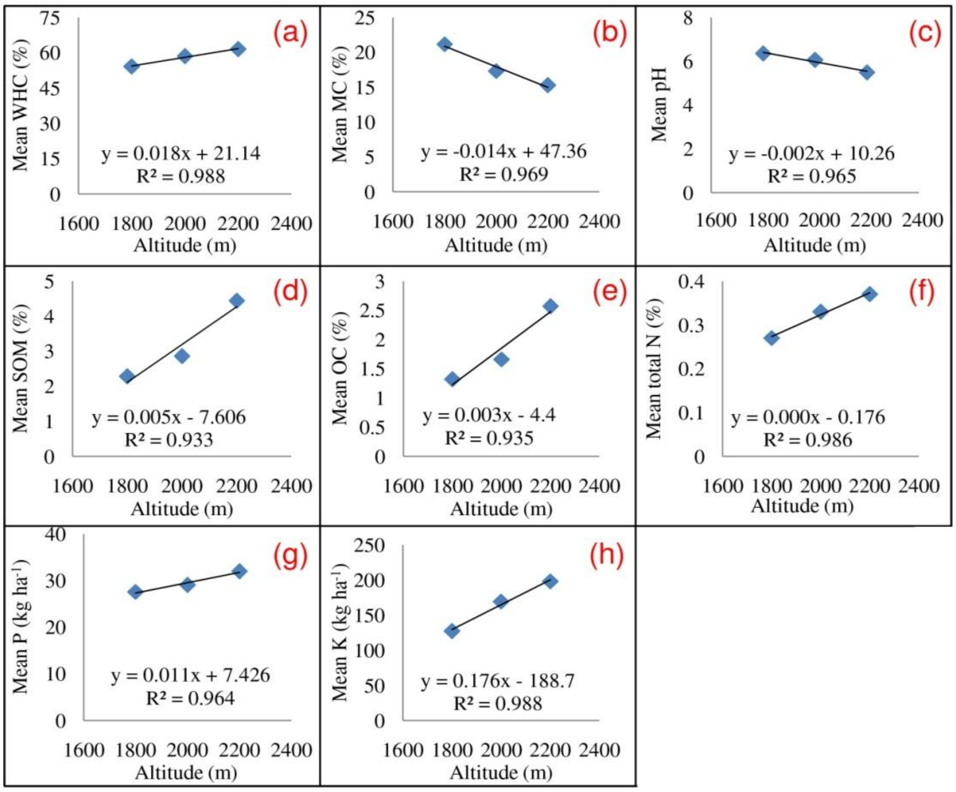

Figure 3: Correlation of different soil parameters with altitude in the study area; **a.** Water holding capacity (WHC); **b.** Moisture content (MC); **c.** pH; **d.** Soil organic matter (SOM); **e.** Organic carbon (OC); **f.** total Nitrogen (N); **g.** available Phosphorus (P), and **h.** available Potassium (K).

Discussion

In the present study, soil colour varied from brown to dark brown (Table 2). Saha *et al*. (2018) and Thakur and Bisht (2020) reported a similar soil colour pattern in temperate forests from Tehri Garhwal and Himachal Pradesh respectively. The mean values of WHC for different sites were within the range of 54.12 to 61.50 %, and were comparable to the values reported by Kumar *et al*. (2013) and Saha *et al*. (2018) from temperate forests of Pauri Garhwal and Tehri Garhwal respectively. The sandy loam textural class of soil was similar, as reported in the earlier investigation by Sheikh and Kumar (2010) in a temperate forest from Tehri Garhwal. The mean per cent value of SOM ranged from 2.38 to 4.44, which was similar to the earlier reported values by Sheikh and Kumar (2010), Gairola *et al*. (2012) and Kumar *et al*. (2013) from the temperate forests of Garhwal Himalaya. The mean per cent value of OC in the present study varied from 1.32 to 2.57 %. These values were within the range reported by Sharma et al. (2010) from Buvakhal, Pauri Garhwal and Gairola *et al*. (2012) from Chamoli Garhwal. The available K varied between 127 kg ha^{-1} and 198 kg ha^{-1}, similar to the values reported by Semwal (2006) from Pauri Garhwal and Sheikh and Kumar (2010). The available P recorded was in the range of 27.56 to 31.98 kg ha^{-1}, comparable to reported values by Rawat *et al*. (2020) from montane forests of western Ramganga Valley, district Chamoli (Uttarakhand).

A negative correlation between soil pH and increasing altitude has been reported by Thakur and Bisht (2020) in a temperate forest from Himachal Pradesh. Similar trend was observed in the present investigation. In the present study a positive correlation has been observed between soil total nitrogen, organic carbon, water holding capacity and soil organic matter, which is in accordance with the reported values of Ram *et al.* (2015) from a temperate forest in Central Nepal, but in contrast to their findings a negative correlation has been found between soil moisture and altitude. An increase in soil organic matter has been observed with increase in altitude (Fig. 3), which can be attributed to slow decomposition process of organic remains at higher altitudes.

It can be concluded from the present results that the altitude has a significant impact on certain physico-chemical properties of soil in temperate forests of Uttarakhand, Western Himalaya.

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