

Assessment of Physico-chemical Properties of Soil along Altitudinal Gradients in a Protected Forest in the Kumaun Himalayas, India

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Abstract: Physico-chemical properties of soil were studied along altitudinal gradients in a protected forest in the Pindari area of Nanda Devi Biosphere Reserve in the Kumaun Himalayas, India. The altitude of study area ranged between 2100-3500 m. In the present study, soil is mainly black, grey and brown in colour and in higher elevations it is skeletal type. Soil texture varied with elevations and the proportion of sand 40.7% to 47.2% increased somewhat with increase in elevation and a reverse trend was observed for clay. The present study also suggests that the higher silt content in site no. 2 and 3 was due to higher precipitation in the form of winter snow. Soil temperature ranged from 2.2°C to 17°C. The pH of the soil ranged from 5.3 to 6.3 and moisture content from 34.5% to 54.8%. Water holding capacity across the sites ranged 40% to 72.2% and the site no. 3 at highest elevation (3500 m) showed maximum water holding capacity but the site no. 2 which was located in 2800 m showed intermediate values. Maximum values of water holding capacity were observed during the rainy season. Soil organic matter was maximum 7.18% in site no. 3 (3500 m) and minimum 2.92% in site no. 1 (2100 m). The organic matter content tended to be higher in the higher altitudinal forests and increased with increasing altitudes.

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1. Introduction

The Himalayan region represents one of the world's richest but fragile ecosystems. It has a vast wealth of natural resources such as water, soils, forests, wildlife and minerals. It gives to India's major rivers such as Indus, Ganges, Sutlej, Yamuna, Brahmaputra and their tributaries. The Himalayan climate varies from tropical to temperate and alpine. Kumaun Himalaya occupies the central sector of great mountains and vegetation thus deserves much attention because of its particular position in the pattern of whole Himalayan vegetation. The major soil groups found in the Himalayan region are Palehumuths (brown-hill soils), Hapludalfs (Sub-montane soils), Cryoborolls (mountain meadow soil), Lithic entisols (skelstal soils), Red loamy soils and their associations thereof (Chaudhary, 1992). The Indian Himalayan soils have been studied by Rawal, 1991; Arya, 2002; Kala et al., 1998; Jina et al., 2011; Joshi et al., 2013. Similarly, physico-chemical parameters of soil in different high altitude ecosystems in different parts of the world have been carried out by various workers (Jenny, 1941; Hanswalt and Whittaker, 1976; Martin and Fletcher, 1943; Bleak, 1970). Soil has been considered as an independent environmental factor that determines subsequent vegetation. The determination of the amount of nutrients in forest soil is of great importance in assessing the soil fertility status and in nutrient cycling studies. Soil is a natural medium for

plant growth and the type of soil in any area is inhabited by a particular type of vegetation, which can grow and flourish in that area only. Vegetation has pronounced effects on many soil properties (Banerjee et al., 1985; Miles, 1985). The present study aimed at assessing the physical and chemical properties of soil along altitudinal gradients in a protected forest in the Kumaun Himalayas, India

2. Materials and Methods

2.1 Study area: The study was conducted in Pindari area which is located (30°5'-30°10'N to 79°48'-79°52'E) in the northern part of Bageshwar district of Kumaun Himalayas, Uttarakhand, India. This area lies at buffer zone of Nanda Devi Biosphere Reserve in Uttarakhand Himalaya, India. The entire area represents a characteristic high altitude environs and falls within an altitudinal range of 2100-3500 m. Climatically, the area is unique and has three season i.e. winter (November to March), summer (April to June) and rainy from middle of June to middle of October. Due to altitudinal and climatic gradients, the natural vegetation changes from temperate to sub-alpine and alpine type. For, the present study, three study sites were selected in the buffer zone of Pindari area of Nanda Devi Biosphere Reserve. The sites selected for the collection and study purpose are as under:-

2.1.2 Site no. 1 (Khati): This study site is connected with road head by a footpath after traveling 22 km

from Song village (Bageshwar district) and is close to the river Pindar. It is located at an altitude of 2100 m. The forest is more of a Pangur (*Aesculus indica* (Colebr. ex. camb) Hk., which is associated with dominant forest of *Quercus floribunda* Rehder, *Junglens regia* L., *Alnus nepalensis* Don., *Acer villiosum* Wall. and *Cedrus deodara* (Roxb.) Loud. This site is moderately disturbed because of its proximity to Khati village and receives moderate disturbances due to the grazing by cattle and collection of forest products by the neighboring villagers.

2.1.3 Site no. 2 (Dawali): The distance between Khati and Dawali is 12 km. This site is located at an altitude of 2800 m and is dominated by colorful Burans (*Rhododendron arboreum* Sm. and *R. barbatum* Wall.) forest associated with mixed forest of *Acer cappadocicum* Gled, *Taxus baccata* L. subsp., *Acer caesium* Wall. ex. Brand, *Abies pindrow* Royle and *Ulmus wallichiana* Plank. This site has very low level of anthropogenic disturbances. The V-shaped valley (both side of Dawali) is drained by river Pindar and very sensitive to geological disturbance i.e. landslides, rock fall and soil-erosion activities.

2.1.4 Site no. 3 (Phurkia): This site is located at an altitude of 3500 m and is close to the Pindari glacier and core zone of Nanda Devi Biosphere Reserve. The distance between Dawali and Phurkia is 7 km. This study area represents to a moist sub alpine scrub and alpine forest. The dominant plant species include Bhoj (*Betula utalis* D. Don), *Acer acuminatum* Wall., *Abies spectabilis* (D. Don) Mirle), *Rhododendron campanulatum* D. Don and *R. anthopogon* D. Don. This is a highly snow prone area of buffer zone which starts receiving snow from last week of November, which can be seen their till the end of March. This site is highly disturbed due to altitudinal migration of tribes who use the area as their summer settlement and collect fuel and fodder apart from the area being used for grazing by their cattle and sheep.

2.2 Atmospheric temperature and humidity: Atmospheric temperature and humidity of the different study sites were recorded on monthly basis with the help of thermo-hygrometer.

2.3 Rainfall: Rain gauge was used to record the rainfall on monthly basis and data from nearest meteorological station were also used.

2.4 Soil sampling and soil analysis: Five soil samples were collected monthly basis from each site, preferably one from center and four from four corners. Soil was cored up to 20 cm depth. These samples were mixed together and a composite sample weighing 200 gm. of the homogenized soil was collected in air-tight polythene bags and brought to the laboratory for physical and chemical analysis. The analysis of different parameters of soil was done by

using Trivedi and Goel, 1996; Walkey and Black, 1934; Ghosh et al., 1983; Allen, 1974 modified methods. Soil colour of different sites was made by using Munsell soil colour chart. Since the present study area is situated within the high altitude zone of Kumaun Himalaya and therefore, month wise collections of soil sample were not possible. The best months for the study of soil were February to December in site no. 1 (Khati), March to December in site no. 2 (Dawali) and April to December in site no. 3 (Phurkia), respectively.

3. Results

3.1 Atmospheric temperature and Humidity:

During present study the temperature varied from 9°C (February) to 25°C (June), 8°C (March) to 20°C (June) and 5°C (December) to 18°C (June) during first year in site no. 1, 2 and 3 respectively. In the second year, it varied from 10°C (February) to 26°C (June), 9°C (March) to 19°C (June) and 4°C (Dec.) to 19°C (July) in site no. 1, 2 and 3 respectively. May and June are the hottest months (25-26°C) and December, January and February are the coldest months. The temperature usually rises from March onward and declines gradually from July onwards. The humidity varied from 30% (May) to 70% (August), 36% (October) to 76% (August) and 41% (October) to 85% (August) during first year in site no. 1, 2 and 3 respectively. During second year, the humidity varied from 34% (October) to 75% (August), 35% (October) to 80% (August) and 42% (October) to 86% (August) in site no. 1, 2 and 3 respectively.

3.2 Rainfall: During snow free period rainfall ranged between 65.2 mm (November) to 469.3mm (August) and 63.85mm (November) to 440.80mm (August) in the study area during the first year and second year, respectively. The monsoon usually strikes in this area around mid-June and persists up to mid-September. The subsequent period, October, November and December constitutes what is generally known as 'retreating monsoon' characterized by a few or no showers at all indicating the beginning of the cold season. The maximum rainfall takes place during July and August (40 to 470 mm) and from September onwards it, however, decreases.

3.3 Soil colour: Majority of soil sample collected from different sites were dark-brown in site no. 1, dark greyish-brown in site on. 2. While, it was black in site no. 3. Thus the colour of different study sites showed much similarity in the present study area.

3.4 Soil texture: Soil texture refers to proportion of mineral particles of different sizes viz. sand, silt clay. The texture of soils in different study sites of Pindari area (values averaged across all samples of each study site) are given in **Table 1**. The soil texture varied with elevation. The proportion of sand 40.7% to 47.2%

increased somewhat with increase in elevation and a reverse trend was observed for clay. The present study also suggests that the higher silt content in site no. 2 and 3 was due to higher precipitation in the form of winter snow.

3.5 Some other physico-chemical parameters of soil: The value of different soil parameters viz. soil temperature, soil moisture, water holding capacity, organic matter and pH were recorded on monthly basis for all the three study sites during our study period and are given in **Table 2, 3 and 4**.

3.5.1 Soil temperature: Soil temperature is an important factor it determines the chemical development of soils and formation of horizons. The soil temperature was measured directly in the field using a mercury soil thermometer. Soil temperature ranged between 4°C (February) to 17°C (July), 4°C (December) to 15°C (June) and 2.8°C (December) to 13.5°C (July) in site no.1, 2 and 3 respectively during first year. Soil temperature varied from 4.3°C (December) to 17°C (June), 5°C (December) to 16°C (July) and 2.2°C (December) to 13.0°C (July) in site no.1, 2 and 3, respectively during second year. It is evident that the soil temperature was higher at lower elevation and it tended to decline along an altitudinal gradient.

3.5.2 Soil Moisture: Soil moisture is the amount of water in a given amount of soil present in the form of capillary water, which is used by plants during the photosynthesis. Soil moisture of Pindari area of Nanda Devi Biosphere Reserve ranged between 36.3% (December) to 43.0% (August), 40.0% (December) to 46.5% (August) and 40.0% (November) to 50.0% (August) during first year in site no.1, 2 and 3 respectively, whereas during second year it varied from 34.5% (December) to 41.7% (August), 40.0% (December) to 47.5% (August) and 43.5% (November) to 54.8% (August) in site no 1, 2 and 3 respectively.

3.5.3 Water holding capacity: Water holding capacity is the amount of water, which is absorbed or retained by the given amount of soil. In Pindari area, it ranged between 40.0% (December) to 53.3% (August), 44.0% (December) to 60.0% (August) and 59.5% (April) to 70.0% (August) during first year in site no. 1, 2 and 3 respectively. During second year it ranged between 43.4% (December) to 51.5% (August), 49.0% (December) to 62.4% (August) and 59.0% (April) to 72.2% (August) in site no. 1, 2 and 3 respectively. Thus the site no. 3 at highest elevation (3500 m) showed maximum water holding capacity but the site no. 2 which was located in 2800 m showed intermediate values.

Table 1: Soil texture of soils in different study sites of the Pindari area (values averaged across all samples of each study site).

Soil Texture (%)	First Year			Second Year		
	Site no. 1 (Khathi)	Site no. 2 (Dawali)	Site no. 3 (Phurkia)	Site no. 1 (Khathi)	Site no. 2 (Dawali)	Site no. 3 (Phurkia)
Sand	41.6	43.5	48.4	40.7	42.8	47.2
Silt	23.7	26.2	23.9	22.8	25.6	24.5
Clay	36.7	30.3	27.7	36.5	31.6	28.3
Total	100	100	100	100	100	100

Table 2: Physico-chemical parameters of soil collected from site no. 1 (Khathi) during the study period.

Sl. No.	Months	Site no. 1 (Khathi)									
		First year of study					Second year of study				
		Soil temperature (°C)	Moisture content (%)	Water holding capacity (%)	Organic matter (%)	pH	Soil temperature (°C)	Moisture content (%)	Water holding capacity (%)	Organic matter (%)	pH
1.	October	11.0	40.5	42.1	3.64	5.7	12.4	38.1	46.0	3.26	5.6
2.	November	8.0	38.0	41.0	3.50	5.7	7.5	36.4	44.0	3.15	5.6
3.	December	6.0	36.3	40.0	3.23	5.6	4.3	34.5	43.4	3.06	5.4
4.	January	-	-	-	-	-	-	-	-	-	-
5.	February	4.0	41.5	44.3	2.89	5.4	5.0	40.6	46.3	2.92	5.3
6.	March	6.3	39.8	43.1	2.93	5.5	9.4	38.5	44.5	3.13	5.4
7.	April	9.4	38.5	42.3	3.27	5.6	11.0	37.8	44.5	3.33	5.7
8.	May	13.5	37.5	43.5	3.40	5.6	15.0	38.5	44.8	3.52	5.9
9.	June	16.0	39.5	47.8	3.80	5.9	17.0	38.8	49.0	3.98	5.9
10.	July	17.0	40.5	52.5	3.82	5.8	16.0	40.4	50.5	3.86	5.8
11.	August	15.4	43.0	53.3	3.75	5.8	16.0	41.7	51.5	3.63	5.7
12.	September	14.8	42.0	47.8	3.71	5.6	16.9	40.2	47.0	3.51	5.7

Table 3: Physico-chemical parameters of soil collected from site no. 2 (Dawali) during the study period.

Sl. No.	Months	Site no. 2 (Dawali)									
		First year of study					Second year of study				
		Soil temperature (°C)	Moisture content (%)	Water holding capacity (%)	Organic matter (%)	pH	Soil temperature (°C)	Moisture content (%)	Water holding capacity (%)	Organic matter (%)	pH
1.	October	9.5	44.0	52.5	4.76	5.6	8.5	43.5	54.5	4.62	5.8
2.	November	7.5	42.3	48.0	4.52	5.6	6.0	40.5	52.0	4.60	5.6
3.	December	4.0	40.0	44.0	4.50	5.5	5.0	40.0	49.0	4.4	5.6
4.	January	-	-	-	-	-	-	-	-	-	-
5.	February	-	-	-	-	-	-	-	-	-	-
6.	March	5.0	44.5	53.5	4.02	5.6	6.0	43.3	55.5	4.30	5.3
7.	April	9.5	42.2	50.0	4.15	5.6	11.0	42.6	54.2	4.65	5.4
8.	May	13.5	42.0	49.0	4.68	5.7	13.0	41.3	51.0	4.85	5.5
9.	June	15.0	43.5	52.0	5.82	5.9	15.5	43.8	55.6	5.73	5.7
10.	July	14.5	46.0	57.5	5.73	6.1	16.0	45.4	59.3	5.97	6.0
11.	August	13.4	46.5	60.0	5.62	6.0	14.0	47.5	62.4	5.91	6.2
12.	September	11.0	44.3	58.5	4.98	5.9	13.2	45.0	56.0	5.04	6.1

Table 4: Physico-chemical parameters of soil collected from site no. 3 (Phurkia) during the study period.

Sl. No.	Months	Site no. 3 (Phurkia)									
		First year of study					Second year of study				
		Soil temperature (°C)	Moisture content (%)	Water holding capacity (%)	Organic matter (%)	pH	Soil temperature (°C)	Moisture content (%)	Water holding capacity (%)	Organic matter (%)	pH
1.	October	7.0	46.0	62.0	6.79	5.9	7.2	49.5	64.0	6.59	6.0
2.	November	4.8	40.0	60.50	6.73	5.8	3.0	43.5	59.5	6.56	6.0
3.	December	2.8	42.0	63.5	6.68	5.8	2.2	46.0	65.0	6.30	5.9
4.	January	-	-	-	-	-	-	-	-	-	-
5.	February	-	-	-	-	-	-	-	-	-	-
6.	March	-	-	-	-	-	-	-	-	-	-
7.	April	6.5	41.0	59.5	6.62	5.6	6.0	44.5	59.0	6.40	5.8
8.	May	10.4	42.5	60.5	6.80	5.9	10.2	46.5	60.0	6.69	5.9
9.	June	13.0	46.0	62.0	7.12	6.0	11.5	49.0	64.5	7.0	6.0
10.	July	13.5	49.5	67.40	7.18	6.1	13.0	51.5	70.3	7.10	6.3
11.	August	11.0	50.0	70.00	6.93	6.2	10.4	54.8	72.2	6.80	6.2
12.	September	9.8	48.0	65.6	6.82	5.9	9.3	52.0	68.5	6.80	6.1

3.5.4 Soil pH: pH of the soil is a measure of hydrogen ion activity, which is measured on a log scale and equal to \log_{10} of hydrogen ion concentration. During the study period first year, soil pH varied from 5.4 (February) to 5.8 (August), 5.5 (December) to 6.1 (July) and 5.6 (April) to 6.2 (August) in site no. 1, 2 and 3, while soil pH varied from 5.3 (February) to 5.9 (June), 5.3 (March) to 6.2 (August) and 5.8 (April) to 6.3 (July) in site no. 1, 2 and 3 respectively during second year. There was not much variation in the pH of soil of different sites.

3.5.5 Organic Matter of Soil: Organic matter is the carbonaceous part of forest litter, which has been freed by microbes and micro-arthropods during the process of decomposition of forest litter. Soil organic matter of Pindari area ranged between 2.89% (February) to 3.82% (July), 4.02% (March) to 5.82% (June) and 6.62% (April) to 7.18% (July) during first year, in site no. 1, 2 and 3 respectively during first year. During second year, it ranged between 2.92% (February) to 3.98% (June), 4.4% (December) to

5.97% (July) and 6.30% (December) to 7.10% (July) in site no. 1, 2 and 3 respectively.

4. Discussion

The soil is mainly black, grey and brown in colour and in higher elevations it is skeletal type. In the present study, soil texture varied with elevation. The proportion of sand 40.7% to 47.2% increased somewhat with increase in elevation and a reverse trend was observed for clay. The present study also suggests that the higher silt content in site no. 2 and 3 was due to higher precipitation in the form of winter snow. Jenny (1941) has stated that silt contents of soils generally increased with increasing precipitation. Soil temperature ranged from 2.2°C to 17°C. The pH of the soil ranged from 5.3-6.3 and moisture content from 34.5% to 54.8%. The average water holding capacity across the sites ranged between 40-72.2%. Maximum values of water holding capacity were observed during the rainy season at all the study sites in the present study. Jina et al., (2011) and Joshi et al., (2013) have reported

the similar trend in soil water holding capacity. Soil organic matter was maximum 7.18% in site no. 3 (3500 m) and minimum 2.92% in site no. 1 (2100 m). The organic matter content tended to be higher in the higher elevational forests and increased with increasing elevations (Rawal, 1991) and according to Hanswalt and Whittaker (1976), the pattern of increased organic matter with elevation is a common feature of mountain soil, which is likely to be related to lower rates of litter decomposition at higher altitude (Martin and Fletcher, 1943; Bleak, 1970). The relationship obtained for different soil parameters in the present study are as follows: Moisture content and water holding capacity showed positive and significant correlation in site no.1 ($r = 0.94$, $P < 0.01$), in site no. 2 ($r = 0.96$, $P < 0.01$) and in site no.3 ($r = 0.97$, $P < 0.01$), respectively. Organic matter exhibited positive and significant correlation with pH of soil ($r = 0.85$, $P < 0.01$), ($r = 0.88$, $P < 0.01$) and ($r = 0.86$, $P < 0.01$) in site no.1, 2 and 3 respectively.

Various other works have also carried out on the physical and chemical properties of soil in the different ecosystems of the Indian Himalayan regions and reported different values of physico-chemical properties of soil. Rawal (1991) had studied different physico-chemical parameters of soil from three elevational belts in the Upper Sarju Catchments of Kumaun Himalayas and reported that the soil temperature ranged from 9.3°C to 13.5°C at lower elevational belt (1600-2000 m), 7.3°C to 8.3°C at middle elevational belt (2100-2600 m) and 4.5°C to 6.2°C at higher elevational range (2500-3400 m). The pH ranged from 6.4 to 6.6. The organic carbon content varied from 2.8% to 3.8%. Kala et al., (1998) reported that the soil pH ranged between 3.8 to 6.1 and organic carbon 4.29 to 33.84% in the Valley of Flowers area, Chamoli, Uttaranchal. Arya (2002) had studied different physico-chemical parameters of soil from two study sites in the Alpine Meadows of Pindari and Milam area of Nanda Devi Biosphere Reserve and reported that the soil pH of Milam area ranged 5.0 to 7.4, soil moisture content between 2.0 to 25% and Organic carbon varied from 4.93 to 25.71%. While the pH of the soil of Pindari area ranged 4.7 to 7.8, moisture content ranged between 15 to 58% and Organic carbon content varied from 2.13 to 21.07%. Jina et al., (2011) have studied physico-chemical characteristics of soil in Oak and Pine forests of Indian Central Himalaya and reported that the soil moisture content ranged between 21% to 65% and water holding capacity varied from 43.34±1.26% to 45.27±0.72% in the degraded and non-degraded forests. In a more recent study, Joshi et al., (2013) have studied physico-chemical parameters of soil in protected forest ecosystem of

Askot Wildlife Sanctuary in district Pithoragarh of Uttarakhand and reported that the soil pH of the sanctuary ranged between 5.3 to 6.5, soil moisture content between 8.44%±3.96 to 20.55±3.90%, water holding capacity varied from 42.1% to 50.95% and the soil organic matter was maximum (5.68%) in high altitude forests site at 2000-2300 m and minimum (3.76%) in low altitude forest site (900-1000 m).

A high organic matter of soil in the present study area than what has been reported by some earlier workers in the different parts of the Indian Himalayan region clearly shows that the soil of Pindari area of Nanda Devi Biosphere Reserve is having high organic matter, which makes it fertile for the growth of vegetation in the area.

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