



Assessment of Soil Physicochemical Properties along an Altitude Gradient in High Altitude Region of Gangotri National Park, Uttarakhand, India

Priyanka Kashyap^{1*}, Anjum Nasreen Rizvi² and V. P. Uniyal¹

¹Wildlife Institute of India, Chandrabani, Dehradun – 248001, Uttarakhand, India; 11priyankakashyap@gmail.com

²Zoological Survey of India, New Alipore, Kolkata – 700053, West Bengal, India

Abstract

The present study was undertaken in the sub-alpine and alpine region of Gangotri valley of Gangotri National Park (GNP) in the Uttarkashi district of Uttarakhand, India. Results showed that selected soils were sandy loam (83%) throughout the region. Soil reactions (pH) vary from 5.00 – 6.28 and showed acidic to the slightly neutral condition. The mean soil Nitrogen (N), and Phosphorus (P) content were calculated $0.37 \pm 0.02\%$ and $0.35 \pm 0.02\%$. The value of NP first increased and then decreased along the elevation. Nitrogen and Phosphorus values ranged from 0.01-0.73 and 0.13-0.87. The correlation analysis among the different soil parameters showed that Soil Organic Carbon (SOC) was positively correlated with soil moisture ($r = 0.661$, $p = 0.038$); Phosphorus ($r = 0.794$, $p = 0.006$) and Nitrogen ($r = 0.964$, $p = 0$). SOC and soil moisture increases at the middle elevation (3400-3500 m and 3700-3800 m) and further decreases along the elevation. This may be explained as the impact of long term human influence and altering the natural habitat in the form of a camping spot for trekkers at this elevation and presence of mixed forest (subalpine deodar, pine, and birch) at 3400-3500 m elevational range. This baseline information on soil parameters in Gangotri valley may further help in climate change study in the current scenario of global warming in relation with above ground vegetation and underground soil biota to understand the soil food web dynamics.

Keywords: Elevation Gradient, Gangotri National Park (GNP), High Altitude Soil, Indian Himalayan Region, Physicochemical Properties

1. Introduction

The composition of the forest stand and ground cover is influenced by the forest soil as it is highly affected by the soil Nitrogen content (N), Phosphorus (P), and soil pH¹. Variation in physiochemical properties of forest soil occurs due to variation in climate, soil flora and fauna activities, weathering processes, topography, vegetation cover and other biotic and abiotic variables. In soil formation, vegetation plays a key role as plants litter from aboveground and root detritus below ground are the major source of Soil Organic Matter (SOM) which influences the soil properties such as pH, Soil Organic Carbon (SOC), soil texture². Changes in soil properties can be seen with disturbances.

Among all nutrient elements availability of soil, Phosphorus is known to affect plant production as more than 80% of the soil Phosphorus gets fixed and become unavailable for plants⁴. In most ecosystems, Nitrogen is considered as a primary limiting micronutrient but in higher altitude alpine and temperate regions availability of Phosphorus may act as a primary limiting element¹⁰. It has been found that the availability/concentration of Phosphorus in the Indian Himalayan Region (IHR) vegetation is less than the other high altitude forests in the world¹⁷. Work has been done on soil characteristics and classification in various regions of IHR by many workers^{3,5,7,8,11,12}. The literature on soil characterization reveals that data has been documented mainly for the lesser Himalayan region in Himachal Pradesh and

*Author for correspondence

Jammu and Kashmir and the other Himalayan States but scanty literature is available for higher altitudinal regions of Uttarakhand. The soil physicochemical properties in high altitude region of the sub-alpine and alpine zone of the Uttarakhand Himalaya are not fully explored. There is a huge void in knowledge about soil physicochemical characteristics along the elevation gradient in high altitudes of the Indian Himalayan region. The present study aimed to assess the physicochemical properties of soil along the elevation gradient in High altitude region of IHR.

2. Materials and Methods

2.1 Study Area

We selected the Gangotri valley of Gangotri National Park as our study area for soil sample collection (Figure 1). Gangotri National Park (30°50'–31°12' N, 78°45'–79°02' E) has a wide altitudinal range (from 1200 to 6000 m) and lies at the upper catchment of the Bhagirathi basin. Gangotri valley of GNP represents the high altitude areas of western IHR. The unique mountain ecosystem of GNP plays host to a large number of animals, plants and herbs. The study area comprises of different vegetation types along the elevation gradient. The highest elevation is covered by ice and bare rocks at a higher elevation (>3800 m), stunted tree line (3500 m - 3800 m), vegetation comprised of Himalayan Birch (*Betula utilis*), subalpine mixed conifer forests with West Himalayan Fir (*Abies pindrow*), Deodar (*Cedrus deodara*) and Blue Pine (*Pinus wallichiana*) being the dominant species.

The area is also rich in faunal diversity and the presence of snow leopard (*Panthera uncia*), Himalayan brown bear (*Ursus arctos isabellinus*), wolf (*Canis lupus*), Musk (*Moschus sp.*), and blue sheep (*Pseudois nayaur*) makes it a special ecosystem for biodiversity conservation.

2.2 Soil Sampling Procedure

The soil has been sampled along the elevation gradient from different vegetation ranging from 3000–4000 m. At a sampling site, leaf litter (if present) as well as the upper layer of soil was removed. Soil samples were collected at 5–15 cm depth using a soil auger (diameter 3 cm). Elevation was categorized in 100 m class (10 classes) along the altitudinal gradient (3000 m–4000 m). From each class of 100 m elevation, seven composite samples were collected (10 elevation class x 7 composite samples from

each class) and 5 subsamples constitute one composite sample. Total of 70 samples were collected along the elevation. These were packed in an airtight polythene bag and transferred to the laboratory of the Wildlife Institute of India for analysis.

2.3 Soil Analysis

Different parameters such as soil reaction (pH), soil moisture, organic carbon, and available Nitrogen, Phosphorus and soil texture were analyzed in the laboratory by using standard protocols. A significant variation in soil properties at the different altitudinal range was observed. The processed soil samples were analyzed for various parameters. The soil pH was determined in 1:2.5 soil:water ratio using the pH meter with glass electrodes; electrical conductivity ($\mu\text{Sc m}^{-1}$) was determined⁶. The organic carbon in the soil was estimated by methods suggested by Walkley and Black¹⁶ (1934); total N content by alkaline potassium permanganate⁹; NaHCO_3 extractable P by spectrophotometer by flame photometer¹³.

2.4 Statistical Analysis

Analyses were performed indicating the relationship between soil physicochemical properties in high altitude region of GNP. To analyze the significant relationship between elevation and physicochemical properties (pH, electric conductivity, soil organic carbon, soil moisture, Nitrogen, and Phosphorus content), Kruskal Wallis analysis of variance (ANOVA) was performed with post hoc test (Dunn test, in FSA package with a critical significance level of 0.05). Spearman's correlation analysis was used between elevation and various soil parameters. All statistical calculations were performed in R platform.

3. Results

The results showed that the GNP soils were sandy loam in texture. The soil in the park was mainly composed of sand (83.8%) followed by clay (16.17%) and a negligible amount of silt (0.02%). The mean soil Nitrogen and Phosphorus content were calculated as $0.37 \pm 0.02\%$, and $0.35 \pm 0.02\%$ respectively (Table 1).

Average Nitrogen content in the GNP soil range from 0.734% at lower elevation to 0.015% at upper elevation. The value of N first decreases along the elevation gradient expect a sudden rise in Nitrogen content at a mid

elevational range of 3400 m – 3500 m and 3700 m – 3800 m (Figure 1c and 1d; Table 2) the change in Nitrogen content were statistically significant (Kruskal Wallis test, $p < 0.05$). The highest recorded mean value of Nitrogen content was 0.652 ± 0.01 (at 3100 - 3200 masl) whereas there is no significant difference in Phosphorus content but decreased along the elevation. The value of available Phosphorus was highest (0.53 ± 0.03) at lower elevation range 3200-3300 masl and lowest (0.19 ± 0.01) at the highest elevation 3800-3900 masl (Table 2) (Figure 1d). The soil in the GNP forest was found to be acidic in nature. Soil pH value ranged from 5.00 – 6.28. Acidity at the mid-elevation range statistically differs at altitudinal range 3300 - 3500m (Figure 1e). Electrical Conductivity (EC) showed the same pattern as pH, decreased along the elevation gradient expect at elevation range 3300 - 3400 (Figure 1f).

Soil organic carbon and soil moisture were higher in lower altitudes as compared to the higher altitudes where

cold and dry climate prevails and the soil remains devoid of any vegetation cover most of the time (Figure 1a, 1b). The correlation analysis among the different soil parameters showed that SOC has significant positive correlations with Nitrogen (correlation coefficient $r = 0.76$, $p < 0.05$), and soil moisture ($r = 0.60$, $p < 0.05$) (Table 2). Soil organic carbon, soil moisture and Nitrogen content were negatively correlated and significantly differs with the elevation (Figures 2, 3, 4).

4. Discussion

The soil in the park was sandy loam and acidic in nature. No particular pattern of acidity has been established with elevation. However, SOC and soil moisture increases at the middle elevation (3400m - 3500 m and 3700 m - 3800 m) and further decreases along the elevation which may be due to human disturbance in the form of camping spot for trekkers at this elevation and presence of mixed forest

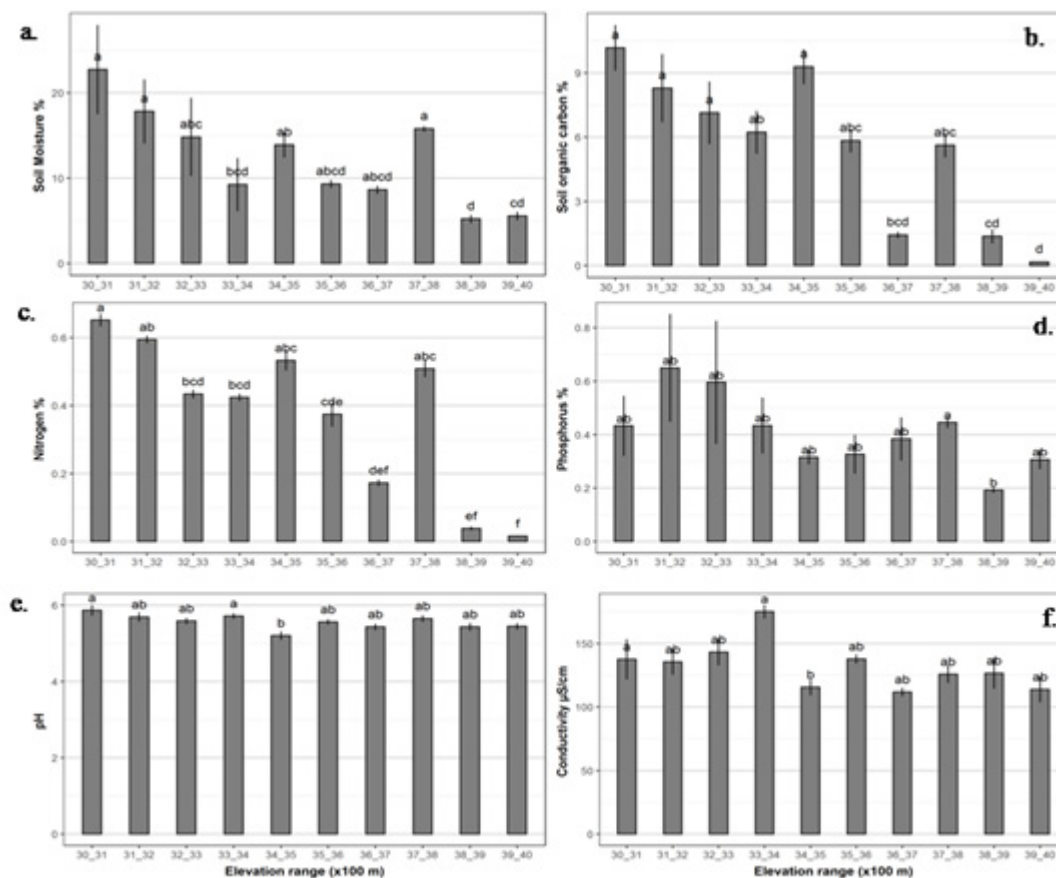


Figure 1. a - soil moisture (SM%); b - soil organic carbon (%); c - Nitrogen content (N %); d - Phosphorus (%); e - pH value; f. - electric conductivity ($\mu\text{S}/\text{cm}$) along elevational gradient 3100-4000 m in Gangotri National Park. Means followed by a common superscript letter are not significantly different by the Post hoc-test at the 5% level of significance ($p < 0.05$).

Table 1. Soil physicochemical properties (Mean \pm SE) in high altitude region of Gangotri National Park (3000 m - 4000 m)

Soil physicochemical parameters	Mean \pm SE
pH	5.55 \pm 0.03
Electric conductivity(μ S/cm)	132.27 \pm 3.4
Nitrogen (% mass)	0.37 \pm 0.02
Phosphorus(% mass)	0.35 \pm 0.02
SM%	12.25 \pm 1.02
OC%	5.55 \pm 0.47
Sand%	83.8 \pm 0.01
Clay%	16.17 \pm 0.008
Silt%	0.02 \pm 0.004

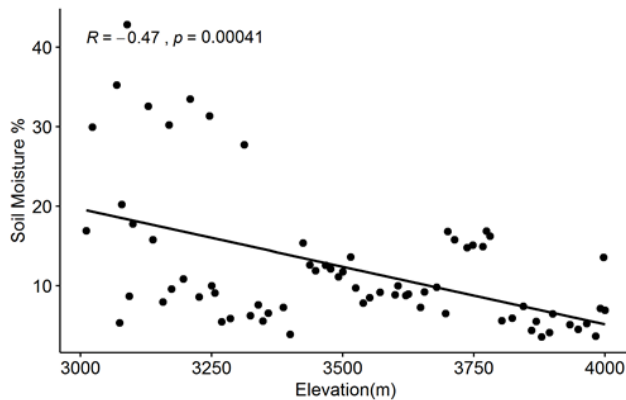


Figure 2. Relationship between soil moisture and elevation in GNP soil. Correlation coefficients and their significance at 0.05 levels.

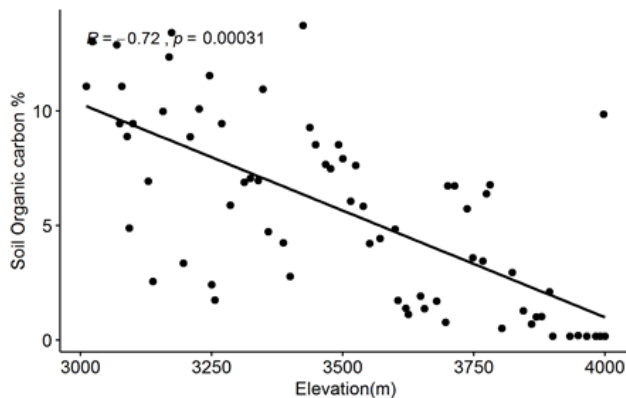


Figure 4. Relationship between Soil organic carbon % and elevation in GNP soil. Correlation coefficients and their significance at 0.05 levels.

Table 2. Correlation coefficients and their significance at 0.05 level between various soil parameters ($p < 0.05$)

	N	P	PH	EC	SM
N					
P	0.25*				
PH	0.22	0.06			
EC	0.21	-0.1	0.35**		
SM	0.69***	0.27	0.17	0.03	
SOC	0.76***	0.16	0.14	0.19	0.6***

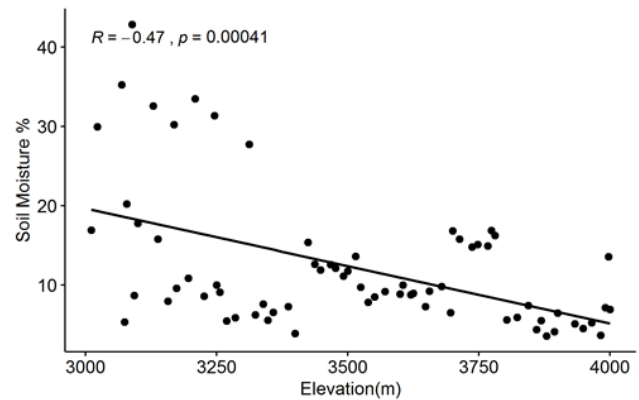


Figure 3. Relationship between Nitrogen % and elevation in GNP soil. Correlation coefficients and their significance at 0.05 levels.

(subalpine deodar, pine and birch) at 3400 m - 3500 m elevational range. The mid-elevation mixed subalpine forest harbors dense vegetation cover of deodar, *betula* and blue pine. The soil was dark in comparison with the color patterns of samples collected from higher elevations. The quantity of N and P is higher at lower to mid elevation may be due to the crowded canopy of subalpine vegetation and presence of preferred amount of soil nutrients¹⁴. Among various elevation range, there is a comparatively good amount of Phosphorus content in birch dominated area at mid elevation range (3500 m - 3800 m) than the other vegetation occupied region along the elevation. This result conforms to the study done in Nanda Devi biosphere reserve forest¹⁵. The correlation analysis indicated that the soil of this area was also rich in nutrients such as Nitrogen and phosphorous at lower elevation where vegetation prevails below tree line up to 3800 m elevation range. The nutrient content of the soil changes along with the changes in temperature as it is

dependent on the decomposition of organic matter. Thus, any future increment in the temperature of this region may increase the soil's organic carbon and nutrients such as Nitrogen and phosphorous. On the other hand, soil samples collected from high altitudes (>3500 m) significantly lacks SOC and soil nutrients except from at 3400 m – 3500 m and 3700 m – 3800 m. This may be explained as the impact of long term human influence in the forms of camping and altering the natural habitat. As an example, the famous trekking destination and pilgrimage site of Chirwasa and Bhojbasa are situated in this range. Soil moisture and soil organic carbon decreases along the elevation, it may be due to lesser or no tree crown cover, harsh weather conditions at higher altitude of alpine region above tree line i.e >3800 m where dry alpine scrub *artemisia* is prevalent. This provides the baseline trend of soil parameter in the study area.

5. Conclusion

The present study in the Gangotri National Park (GNP) focused on the availability of nutrients in soils along the altitude gradient. Vegetation shifts from lower elevation sub alpine deodar, blue pine, birch dominated forest to alpine scrub at high elevation range which results in change in soil macronutrient properties. The lower to middle altitude of GNP contains significantly increased SOC, macronutrients $\text{KMnO}_4\text{-N}$, Olsen-P, $\text{NH}_4\text{OAc-K}$ and soil moisture as compared to high altitude ranges. There was a trend of increment in Soil Organic Carbon, Nitrogen and Phosphorus content due to shifting from higher to the lower altitude of the ecosystem. Finally, there was significant negative correlation of SOC, TN and soil moisture with elevation while the positive correlation between soil organic carbon, Nitrogen content and soil moisture was observed. Improvement in SOC build-up and soil macro-nutrients along with altitudes ranged were significant findings of the ecosystem. Therefore, this study may further help in climate change study in the current scenario of global warming in relation with above ground vegetation and underground soil biota to understand the soil food web dynamics. Further research is required to extrapolate (from the small ecosystem to a large Indian Himalayan extent) these altitude based nutrient availability and the concept (shifting of nutrient from higher to lower altitude).

6. Acknowledgements

We express our sincere thanks to Dr. V. B. Mathur, Former Director, WII and Dr. G. S. Rawat, Former Dean, WII, Dr. S. Sathyakumar, Nodal Scientist, DST-NMSHE for their guidance and support. We are thankful to the Uttarakhand Forest Department for granting us the research permission and for necessary support and cooperation. We thank Gunjan Gulati (Project assistant), Neeraj, Naresh, Akhil, Uttam, Anil who helped us as field assistant and guide. We are also thankful to the National Mission on Himalayan Studies (NMHS), Ministry of Environment, Forests and Climate Change, Government of India for providing funding support and Department of Science and Technology (DST), Government of India under DST grant no.: DST/SPLICE/CCP/ NMSHE/TF-2/WII/2014[G] dated 26.08.2014.

7. Reference

1. Bhatnagar HP. Soils from different quality Sal (Shorea robusta) forest of Uttar Pradesh, India. Tropical Ecology. 1965; 6:56–62.
2. Chapman JL, Reiss MJ. Ecology: Principles and applications. UK: Cambridge University Press; 1992.
3. Handoo GM. Organic matter fractionation in some soil profiles of Jammu and Kashmir State developed under different bio and climosequences. [Ph.D. (Agri.)]. Thesis submitted to Himachal Pradesh Krishi Vishva Vighyalaya Palampur (H.P.), India. 1983. p. 1–128.
4. Holford ICR. Soil Phosphorus: Its measurement and its uptake by plants. Australian Journal of Soil Research. 1997; 35:227–39. <https://doi.org/10.1071/S96047>
5. Hoon RC. Distribution of Sesquioxides silica and organic matter in forest soil profiles of Kullu Hill area. Indian forest. RecI 3. 1936.
6. Jackson ML. Soil chemical analysis. New Delhi, India: Prentice Hall of India Pvt Ltd; 1973. p. 448.
7. Jaggi RC, Kanwal RS, Dixit SP. Evaluation of methods for available Phosphorus for wheat in wheat growing valleys of Himachal Pradesh. Journal of the Indian Society of Soil Science. 1990; 38:56–60.
8. Joshi G, Negi GCS. Soil physico-chemical properties along soil profile of two dominant forest types in the Western Himalaya. Current Science. 2015; 109:798–803.
9. Kjeldahl JZ. A new method for the determination of Nitrogen in organic bodies. Analytical Chemistry. 1883; 22:366.
10. Korner Ch. The nutritional status of plants from high altitudes: A worldwide comparison. Oecologia. 1989;

- 81:379–91. PMID: 28311193. <https://doi.org/10.1007/BF00377088>
11. Mahapatra SK, Walia CS, Sighu GS, Rana KC, Tarseem L. Characterization and classification of soils of different physiographic units in the sub-humid ecosystem of Kashmir region. *Journal of Indian Society of Soil Science*. 2000; 48:572–7.
12. Mukherjee SK, Das SC, Raman KV. Review of soil research in India. New Delhi: *Journal of Indian Society of Soil Science*; 1971.
13. Olsen SR, Cole W, Watanable FS, Dean LA. Estimation of available Phosphorus in soils by extraction with sodium bicarbonate. *Methods of Soil Analysis Circ*. 1954; 939.
14. Sigdel SR. Attitudinally coordinated pattern of plant community structure in the Shivapuri National Park, Nepal. *Banko Janakari*. 2008; 18(1):11–7. <https://doi.org/10.3126/banko.v18i1.2161>
15. Tiwari SD, Joshi R, Rawat A. Physico-chemical properties of soils in cool-temperate forests of the «Nanda Devi Biosphere Reserve» in Uttarakhand, India. *Journal of Ecology and the Natural Environment*. 2013; 5(6):109–18. <https://doi.org/10.5897/JENE12.097>
16. Walkley A, Black IA. An examination of the Degtjareff method for determining Soil Organic Matter and a proposed modification of the chromic acid titration method. *Soil Science*. 1934; 37:29–38. <https://doi.org/10.1097/00010694-193401000-00003>
17. Zobel DD, Jha PK, Behan JM, Yadav UKR. A practical manual for ecology. Kathmandu, Nepal: Ratna Books Distributor; 1987.