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Vegetation and physicochemical analysis in sacred natural forests of Kumaun Himalaya

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Abstract

The study of floristic diversity in any forest and its expansion are incomplete without taking consideration of plant-soil interactions. With this point, present study was undertaken in four temperate forests with three forest types i.e. banj- oak (*Quercus leucotrichophora*), rianj-oak (*Q. lanuginosa*) and mixed-oak (*Quercus leucotrichophora, Q. floribunda* & *Q. lanuginosa*) in Champawat, Kumaun Himalaya. The aim of the study was to assess the physical and chemical properties of soil in relation to the forest structure, composition and forest health. Chemical properties of the soil, i.e., total nitrogen (N), available phosphorus (P), available potassium (K), organic carbon (C), soil organic matter (SOM), pH and C:N ratios were analyzed for two different depths viz., (i) (0–15 cm), (ii) (15–30 cm) in all the selected forest types. Three plots each of 50 × 50 m were laid in each studied site at hill base, hill mid and hill top were laid. Phytosociological and diversity parameters viz. total basal cover (m^2 ha^{-1}), stem density (trees ha^{-1}), tree species richness (SR), and Shannon–Wiener diversity index (H′) were also calculated for each forest type. The altitude doesn't show any impact on the studied physicochemical properties of the soil whereas average organic matter shows a highly significant relationship with average carbon (r= 0.998; p<0.01). Potassium shows moderate significant relationship with average carbon and average organic matter (r= 0.610 and 0.622 respectively; p<0.05). Phosphorus shows slight significant relationship with Water Holding Capacity (WHC) of the soil (r= 0.588; p<0.05). No relationship between altitude and C was observed, which may be due to different composition of forest types along the altitudinal gradient and their differential decomposition rates. This study shows the stem density varied in between 606-1067 trees ha^{-1} and 45.20-71.78 m^2 ha^{-1} total basal area was recorded from studied forest. The possible reason being luxuriant vegetation and undisturbed nature of these forest types due to their sacredness, which is evident from higher values of diversity and other phytosociological parameters.

Keywords: *Quercus leucotrichophora, Rhododendron arboretum,* floristic diversity

Introduction

Sacred Natural Forests (SNFs) play an indispensable role in conservation of soil, water, and habitat of different life forms and maintain all the biotic and abiotic factors of a landscape. Forest soil influences the composition of forest stand and ground cover as well as rate of tree growth (Bhatnagar, 1965) [4]. Physicochemical characteristics of forest soils vary in space and time because of variation in different environmental factors i.e. climate, topography, weathering processes, vegetation cover and several other biotic and abiotic factors (Paudel and Sah, 2003; Sheikh and Kumar, 2010) [42, 55] that improve the soil structure, infiltration rate and Water Holding Capacity and aeration (Chapman and Reiss, 1992; Ilorkar and Totey, 2001; Kumar *et al*., 2004) [10, 19, 31]. The nutrient thus, returned in the soil, exerts a strong feedback on the ecosystem processes (Pastor *et al*., 1984) *et al* [41]. Plants are the main source of soil organic matter, which influence the physicochemical characteristics of soil such as, texture, pH, water holding capacity and nutrients availability (Johnston, 1986) [24]. The nature of soil profile, pH and nutrient cycling in soils and vegetation assessment are used to determine the health of forests. The Kumaun Himalayan forests have variation in the topography, climate, soil condition and biodiversity, which form a complex ecosystem (Mehta *et al*. 2022) [37]. Since, the vegetation zones in this region clearly reflect climatic and edaphic variations (Bhatt, 1981; Bhatt and Purohit, 2009) [5, 6]. Most of the forests ranging from subtropical to subalpine are dominated by different species of oak (*Quercus*) at different altitudinal zones of Kumaun Himalaya (Mehta, *et al*. 2021) [36]. Oaks have been impacted by many environmental variables and soil is one of them imperative natural resources on which all forms of terrestrial life co-exist. In Kumaun Himalaya, oaks are the major forest forming species spread over a large part of the landscape. Banj-oak (*Quercus leucotrichophora* A. Camus) is a deep-rooted and moderate-sized evergreen tree that occurs in the moist and cool aspects in the lower Himalayan temperate forests between altitudes 1000-2300 m asl (Singh and Singh, 1987; Joshi, Negi, 2015, and Mehta *et al*, 2019) [57, 26, 35]. The other species of oaks like Rianj-oak (*Q. lanuginosa* Beck.) ranges in between 1200-2400 m asl, and is found in small pockets, whereas Kharsu- oak (*Q. semecarpifolia* Sm.) is a climax species that starts from 2400 m altitude and grows up to 3600 m altitude (Mehta *et al*. 2019) [35]. Tijonj/Moru oak (*Quercus floribunda* Lindl. *ex* A. Camus) is found in mid altitude regions (temperate to sub-alpine) and ranges from 1800-2800 m asl and Phalyant oak (*Q. glauca* Thunb.) is a road side or kind of avenue tree associated with *Quercus leucotrichophora*, *Myrica esculenta* Buch.-Ham.

ex D.Don.and *Rhododendron arboreum* Sm. in 1000-1800 m asl.

The oak dominated forests play a vital role in ecosystem services like provisioning a variety of goods and services to cultural services which provide quality fuel wood, fodder, manuring leaves, NTFPs (Non Timber Forest Products), water conservation, soil stability, maintenance etc. Some previous studies about physicochemical characterization of soil were also done by researchers in various forests of Kumaun and Garhwal Himalaya (Khera *et al*., 2001; Sharma *et al*., 2010; Gairola *et al*., 2012; Joshi *et al*., 2013; Mehta *et al*., 2014; Joshi and Negi, 2015; Bharti *et al*., 2016, Tewari *et al*., 2016; Upreti *et al*., 2016) [28, 53, 15, 27, 34, 26, 3, 61, 62]. At the same time the information on physical and chemical properties of soils and phytosociological studies of different oak dominated SNFs in temperate region of Kumaun Himalaya is meager. Hence, the present study aims to:

- Assess the soil physicochemical profile w.r.t. phytosociological attributes of tree layer in different oak dominated sacred forests
- correlate the soil physicochemical properties with altitude and vegetation

Material and Methods

Study Area

The randomly distributed survey was done in different oak dominated SNFs of Champawat district, Kumaun Himalaya, Uttarakhand (Figure 1). The present study was conducted in four sites along an elevation gradient of 1750-2490 meters. The detailed description of the studied sites is given (Table 1). The climate of Champawat is of humid subtropical type distinct by wet and dry season, and moderate climate throughout the year. The average amount of precipitation for the year 2018 was 1239.5 mm while the wettest month of the year was July with 358.1mm precipitation. For the detailed study of plant biodiversity and other vegetation parameters, the area was divided into three sites each on eastern and western aspects along the elevation gradient i.e., hill base (1700-1900 m), hill mid (1800-2100 m) and hilltop (1900-2500 m).

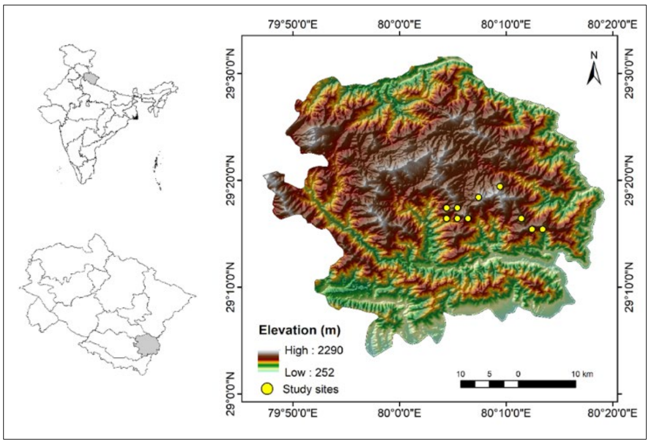

Fig 1: Map of the studied sacred forests

Vegetation sampling, soil sampling and analysis

Soil samples were collected from four SNFs with three dominated forest types i.e. banj-oak, rianj-oak and mixed-oak in Champawat district. Three plots each of 50 × 50 m and 10 quadrats (10 × 10 m each) within each plot were laid in each studied site at hill base (B), hill mid (M) and hill top (T) for knowing the physicochemical status of soil in all studied forests. For knowing the phytosociological status, 10 quadrats (10 × 10 m each) within each plot for trees and saplings were laid down. Five soil samples (one from center and four from corners) following Z-scheme were collected from each quadrats. Soil was cored up to 0-15 cm to 15-30 cm depth. These samples were mixed together and a composite sample weighing 200g of the homogenized soil was collected in air tight polythene bags, and brought to the laboratory for physical and chemical analysis (Rana and Samant, 2011) [46]. The soil samples were oven dried at 45 °C for 24 hours to reduce the moisture. Analytical procedure for soil physicochemical characterization was done by various methods *viz.*, soil texture by sieve method (Piper, 1966) [44], soil moisture (Jackson, 1958) [20], water holding capacity (Piper, 1950), soil bulk density by gcm^{-3} (Black, 1965) [8], soil porosity (Gupta and Dhakshinamoorthy, 1980) [16], pH (Jackson, 1958) [20], soil organic carbon by wet digestion method (Walkley and Black, 1934) [65], total nitrogen by Kjeldahl digestion method (Kjeldahl, 1983) [30], available phosphorus by 0.5 M $NaHCO_3$ (pH 8.5) extraction method (Olsen and Sommers, 1982) [40], available potassium by 1 N NH_4OAc (pH 7.0) extraction method (Black, 1965) [8]. All the soil analytical experiments were performed in Soil Analytical Laboratory (SAL) and Central Laboratory of G. B. Pant National Institute of Himalayan Environment, Kosi-Katarmal, Almora, Uttarakhand.

Statistical analysis

Vegetation was analyzed for density, frequency, abundance, relative density (RD), relative frequency (RF), Importance Value Index (IVI), total basal area (TBA), relative total basal area (RTBA) and Shannon-Weiner Diversity (H′) (Shannon and Weaver, 1949; Curtis and McIntosh, 1950; Phillips, 1959) [51, 12, 43]. All determinations of physical [moisture content (MC), water holding capacity (WHC), pH] and chemical [average carbon (C), average organic matter (OM), nitrogen (N), potassium (K), phosphorus (P)] properties were conducted in three replicates. The value for each sample was calculated as mean of all replicates with ± standard error. Significant difference among means of the samples were tested using Duncan Multiple Range Test (DMRT) on mean values by one way analysis of variance (one way-ANOVA) using SPSS software (16.0 version). For knowing the relationship between different variables i.e. altitude and studied phytosociological and physicochemical parameters, Pearson’s correlation coefficient was performed by using the same software.

Results and Discussion

Vegetation assessment

A total of 14 tree species of plants were reported from the study area. At hill base, Hingla Devi (mixed oak forest) was the highly dense forest with 980 trees ha^{-1} followed by Banlekh (Banj oak forest) with 770 trees ha^{-1} and lowest (560 trees ha^{1}) in (banj- rianj oak forest) (Table 2). At hill mid, the lowest stem density was reported in Kranteshwar (620 trees ha^{-1}) and highest in Hingla Devi (1160 trees ha^{-1}) whereas at hilltop, the lowest density was reported in Gorakhnath (530 trees ha^{-1}) and highest in Hingla devi (1060 trees ha^{-1}). In case of the Total Basal Area (TBA) of trees, highest (2735.54 m^2 ha^{-1}) was reported from Gorakh Nath hill top, however, lowest was reported from Banlekh hill top (1067.24 m^2 ha^{-1}). The diversity index (H′) ranged from 1.01 (Kranteshwar hill top) to 2.01 (Hingla Devi hill mid). IVI for all the sites ranged from 203-300(%). The highest IVI (300%) was found in Gorakh Nath hill top and hill base. The density of saplings was highest in Banlekh hill mid (510 ha-1) followed by hill top (350 ha^{-1}) wherein two forests, the density of saplings were recorded zero. TBA of saplings was highest in Hingla Devi hill mid (217.25m^2 ha^{-1}) followed by Banlekh hill mid (181.35 m^2 ha-1) and overall ranges were found in between (0-217.25m^2 ha^{-1}) in different forests (Table 2).

Physicochemical assessment of soil

Moisture content did not affect the density of forest. A statistically significant difference ($p<0.05$) was found between the values along the forest stand as well as altitude. The highest moisture content was recorded in the soil of Gorakh Nath hill top (31.83%), however, minimum was recorded from the hill base of Hingla Devi (12.10%). The Water Holding Capacity also did not show the direct impact on forest composition and health. Maximum WHC was recorded from hill base of Gorakh Nath followed by Hingla Devi hill base (57.51%), Hingla Devi hill top (47.01%), and others, minimum WHC was found from the soil of Kranteshwar hill base (18.27%). Hydrogen ion concentration (pH) ranged from 5.40 to 7.23. There was a significant relation between pH and forest health and composition due to their basic behavior as shown in the results. Highest pH was observed from the soil of Hingla Devi hill base (7.23), however, minimum was recorded from Banlekh hill base (5.40). Average carbon of the studied soil ranged from 0.26 to 0.98%, which were significantly differing ($p<0.05$) from each other. Carbon composition was high in the soil of climax forest of Gorakh Nath hill base where no sapling and seedling reported (0.98%). Average organic matter ranged from 0.43 to 1.42% and was differing significantly with each other. The highest Organic Matter was present in the soil of Kranteshwar hill base and hill mid (1.42% each) affect the regeneration pattern of the forest where as the low organic matter found in Kranteshwar hill top resulted in higher regeneration. Nitrogen content ranged from 0.06 to 0.88% in the soil of studied sacred forests, there was a significant difference between the nitrogen content. The maximum nitrogen content was recorded from the soil of Kranteshwar hill top (0.88%) and minimum was recorded from Hingla Devi hill mid (0.06%). Nitrogen content showed the higher regeneration ratio in both the forests. Potassium content ranged from 0.33 to 87.13 ppm. The values of K statistically differed with each other significantly ($p<0.05$). The highest potassium content was recorded from the soil of Kranteshwar hill mid (87.13 ppm). However, minimum was recorded from Banlekh hill top (0.33). Phosphorus content ranged from 0.50 to 24.63 ppm, which was significantly differing with each other ($p<0.05$; Table 3). The maximum P content was found in the soil of Gorakh Nath hill top (24.63 ppm) followed by Gorakh Nath hill base (24.43 ppm), and others. However, minimum was recorded from Kranteshwar hill top (0.50).

Relationship among altitude and different physicochemical properties of soil

Relationship among different parameters was analyzed by Pearson's correlation coefficient. During the present study it was observed that altitude did not show any impact on the studied phytosociological parameters and physicochemical properties of the soil (Table 4). In case of phytosociological parameters, sapling RD and diversity index showed a negative highly significant relationship with tree RD ($r= -1.000$, $p<0.01$ and $r= -0.951$, $p<0.01$). Moisture content and pH showed a moderate significant relationship with tree diversity index ($r= -0.585$, $p<0.05$ and $r= -0.708$, $p<0.01$). Besides these, other physicochemical parameters of soil did not show any relationship with phytosociological parameters (Table 4). Maximum studied physico-chemical parameters did not show any relationship with each other (Table 4). However, average organic matter showed a highly significant relationship with average carbon ($r= 0.998$; $p<0.01$). Potassium showed the moderate significant relationship with average carbon and average organic matter (r= 0.610 and 0.622 respectively; $p<0.05$). Phosphorus showed the slight significant relationship with WHC of the soil ($r= 0.588$; $p<0.05$).

The structure of soil and its physical constitution like size and shape of soil particles in the soil classify the nature of soil (Jongmans *et al*., 2001) [25] which helps to control the erosion and increase the fertility of soil (Sharma and Bhatia, 2003) [52]. The physicochemical properties are responsible for determining the nutrient status of the soil, which vary according to the nature of the climate, parent material, physiographic position and the vegetation (Behari *et al*., 2004) [2]. Forest litter plays an important role in the formation of soil. The decomposition rate of forest litter depends on the favourable environmental conditions such as moisture and temperature. Moisture content in the soil of studied sites varied from 12.10 to 31.83%. These values of moisture content reported in the present study are higher than the values reported for Kumaun Himalaya (Khera *et al*., 2001) [28] and Garhwal Himalaya (Nazir and Wani, 2009), whereas they are similar to the values recorded by Sharma *et al*. (2010) [54]. The variation in moisture content in different sites of the study area can be attributed to the microclimatic conditions and WHC of the soil but statistically it is proved that the altitude and WHC did not affect the moisture content in the present study. So it is important to further investigate the moisture content with other ecological parameters. The vegetation composition is an important aspect to define the moisture content of the soil (Jha and Pande, 1980) [21]. The soil moisture content was higher in the higher altitude forests and was lower in low altitude forests and they also reported that oak forests are characteristically moist in nature (Singh and Singh, 1986).

In the present study, WHC ranged from 18.27 to 60.16% but Saha *et al*. (2018) [48] reported the range of WHC from 62.13-67.70% (for *Q. leucotrichophora* forest of Pauri Garhwal) of Western Himalaya. These reported values are much higher than the recorded values during our study. WHC values were estimated between 28.10 and 81.20% by Kumar *et al*. (2004). WHC for *Q. leucotrichophora* forest and *Q. semecarpifolia* in different forests of Western Himalaya were reported 67.17% and 99.91% respectively (Sharma *et al*., 2010) [54]. Values of our study are comparable with other studies and ranges within these studies. Highest WHC was reported in oak (*Q. leucotrichophora*) forest and lowest in pine (*Pinus roxburghii*) forest (Sheikh and Kumar, 2010) [55].

pH is an important property of soil because it governs the nutrients availability, microbial activity under soil and physical condition of the soil. Generally, pH range of the fertile soil is between slightly acidic to basic (5.5 to 7.2), which supports the results of our study that means our forest sites are rich in nutrients. pH ranged between 4.4 to 5.5 in black spruce, hemlock and birch, 5.5 to 6.9 in deciduous forests, and 7.0 to 8.0 in grasslands (Verma, 1977) [63]. pH in coniferous forests of Central Himalaya was reported in between 5.5 to 6.5 by Bisht and Lodhiyal (2005) [7]. According to a study pH gradually decreased with rise in altitude (Mandal *et al*., 1990) [33]. Our results are somewhat similar with the study of Mandal *et al.* (1990) [33]. Higher levels of organic matter having greater number of cation exchange and due to this level of soil pH decreased (Naiman *et al*., 1994; Hodges, 1996) [38, 17]. However, during our study we did not find any relationship between organic matter and pH and it was confirmed by Pearson's Correlation analysis. Grand fir and Norway spruce have more acidified soil than oak and beech (Xu *et al*., 2006) [66].

Carbon stored in the soil is known as soil carbon and it is a part of OM. Many other important elements such as calcium, hydrogen, oxygen and nitrogen are also available in the OM. Basically OM is made up by the decomposition of plant and animal materials and it acts as a sink and source of carbon (Kirschbaum, 2000) [29]. Forest plays an important role in the form of decomposed leaves, twigs, stems, flowers and fruits to make up of organic matter which forms the carbon (Schnitzer, 1991) [50]. Many environmental factors influence the soil carbon in which altitude is most important. In mountainous areas the soil carbon stock increases with elevation (Lal, 2005) [32]. Our results show that there is a strong correlation between OM and soil carbon but in case of the altitude, it did not affect the carbon stock in the studied forests.

Variation in soil properties are influenced by many biotic as well as abiotic factors such as topography-induced microclimate differences, altitude, parent material and vegetation community (Johnson *et al*., 2000) [23]. In case of the microclimatic variations altitude is the most effective factor which affects the weathering rates and leaching intensity, showing the changes in soil responses such as amount and quality of organic matter (Hutchins *et al*., 1976; Dahlgren *et al*., 1997) [18, 13]. Soil organic matter was significantly higher in protected sites than grazed site ($P<0.05$) while there was no difference in OM contents between protected sites (Qasim *et al*., 2017) [45].

There are mainly three macronutrients i.e. nitrogen, phosphorus and potassium which are required in large quantities to support the plant growth and development. For the growth and development, plants directly intake the nitrogen from soil in the form of ammonia, nitrate and nitrite (Reich *et al*., 1997; Schimel and Bennett, 2004) [47, 49]. In a forest ecosystem nitrogen content affects the productivity, species diversity, community succession and sustainability (Vitousek and Howarth, 1991) [64]. Nitrogen intake by plants and its return into soil through litter fall is one of the important features of forest ecosystem (Chen *et al*., 2000) [11]. During our study it was found that the high altitude region of the Kranteshwar forest was rich in nitrogen content and it may be due to the higher litter fall. Ecological studies on soil showed that the soil nitrogen availability and net nitrogen mineralization and nitrification rates vary not only with tree species composition but also with altitude and other geographical features of the forest (Bargali *et al*., 1998; Zhong and Makeschin, 2004) [1, 67]. The available soil phosphorus values showed the irregular pattern in studied forest sites. Phosphorus exists in the nature in a number of organic forms. A study conducted in forest sites of the Eastern Himalaya reported that the distribution of phosphorus followed no definite trend, though soils at higher altitude exhibited higher available phosphorus content (Mandal *et al*., 1990) [33]. Similarly during our study we did not find any definite trend of phosphorus content along the altitudinal gradient. The phosphorus content in soil is mainly determined by a number of factors such as parent material, climate topography and micro-organisms (Smeck, 1985) [58]. In the present study we have found a positive correlation between WHC and phosphorus content, which means WHC positively, affected the phosphorus. It is stated that the dynamics of phosphorus in the soil is closely related with the dynamics of carbon, nitrogen and sulphur (Sood and Kanwar, 1986; Stewart and Tiessen, 1987) [59, 60].

Potassium plays an important role in photosynthesis, water regulation by maintaining water status of cells, enlargement of fruit size and resistance to insects and diseases. It plays important role in transpiration, respiration, influencing enzyme activity and synthesis of carbohydrate and proteins (Brady, 1996) [9]. Along the altitudinal gradient the availability of potassium was increased in Garhwal Himalaya (Jha *et al*., 2002; Dimiri *et al*., 2006) [22, 14]. But our study did not show any definite trend of potassium content along the altitude. Total potassium varies along the altitude and higher content was found in soil surface in the form of exchangeable potassium which later converts as soil solution (Dimiri *et al*., 2006) [14]. Average carbon content and OM impacted positively the content of potassium and correlated with each other.

Table 1: Characteristics of selected sacred forests of Kumaun Himalaya

S. No.	Study sites		Altitude (m asl)	Geo-coordinates		Species composition	Dominant species
				Latitude (N)	Longitude (E)		
1	Kranteshwar	T	2168	29°18′25.0″	80°07’54.6″	*Quercus leucotrichophora, Q. lanuginosa, Myrica esculenta, Rhododendron arboreum, Lyonia ovalifolia, Pinus roxburghii*	*Quercus lanuginosa, Q. leucotrichophora*
		M	2094	29°18′26.3″	80°07’48.8″		*Quercus lanuginosa, Quercus leucotrichophora, Myrica esculenta*
		B	1850	29°19’16.3″	80°09’18.0″		*Quercus leucotrichophora, Quercus lanuginosa, Rhododendron arboreum*
2	Banlekh	T	2040	29°16’44.4″	80°06’06.6″	*Quercus leucotrichophora, Myrica esculenta, Rhododendron arboreum, Lyonia ovalifolia, Pinus*	*Quercus leucotrichophora, Rhododendron arboreum, Lyonia ovalifolia*
		M	1860	29°16’55.5″	80°05’47.1″		*Quercus leucotrichophora, Rhododendron, Myrica esculenta, arboreum, Lyonia ovalifolia*

		B	1750	29°17’03.7″	80°05’35.0″	*roxburghii, Prunus ceresoides, Cedrus deodara* and *Cupressus torulosa*	*Quercus leucotrichophora, Pinus roxburghii, Cedrus deodara, Cupressus torulosa*
3	Gorakh Nath	T	1900	29°15’44.4″	80°13’09.8″	*Quercus leucotrichophora, Q. lanuginosa, Myrica esculenta, Rhododendron arboreum Lyonia ovalifolia*	*Quercus leucotrichophora, Q. lanuginosa*
		M	1850	29°15’45.0″	80°12’53.1″		*Quercus leucotrichophora, Q. lanuginosa*
		B	1780	29°16’25.0″	80°11’40.2″		*Quercus leucotrichophora, Q. lanuginosa, Lyoniaovalifolia*
4	Hingla Devi	T	2490	29°16’19.6″	80°04’42.1″	*Quercus leucotrichophora, Q.lanuginosa, Q. floribunda, Myrica esculenta, Rhododendron arboreum, Lyonia ovalifolia, Pinus roxburghii, Pyrus pashia, Cedrus deodara, Cupressus torulosa, Cornus capitata, Lindera pulcherrima*	*Quercus leucotrichophora, Q. lanuginosa, Q. floribunda, Myrica esculenta, Rhododendron arboreum*
		M	2013	29°17’49.8″	80°04’42.1″		*Quercus leucotrichophora, Q. lanuginosa, Myrica esculenta, Rhododendron arboreum*
		B	1760	29°17’06.7″	80°05’45.0″		*Quercus leucotrichophora, Lyonia ovalifolia, Pinus roxburghii*

Note: T- Hill top, M- Hill mid, B- Hill base, altitude (m asl)-altitude meter above sea level

Table 2: Phytosociological analysis of studied sacred forests

Sites	Location of hill	Tree				Sapling			
		D	**TBA**	**IVI**	**H′**	**D**	**TBA**	**IVI**	**H′**
Kranteshwar	T	640	1709.03	220.79	1.01	240	95.58	79.21	0.62
	M	620	1496.96	247.05	1.36	180	58.64	52.95	0.57
	B	560	2345.06	276.31	1.47	60	45.62	23.69	0.33
Banlekh	T	700	1067.24	214.92	1.11	350	136.56	85.09	0.82
	M	800	1493.3	203.92	1.35	510	181.35	96.08	0.92
	B	770	1960.1	233.88	1.61	290	108.03	66.12	0.7
	M	660	1284.85	283.52	1.16	60	24.85	16.48	0.21
	B	600	1312.9	300	1.3	0	0	0	0
Hingla Devi	T	1060	2095.71	253.15	1.89	260	117.4	46.85	0.62
	M	1160	2658.57	250.84	2.01	300	217.25	49.16	0.78
	B	980	2423.59	256.95	2	220	160.73	43.05	0.62

Note: D- Density (trees ha $^{-1}$), TBA- Total Basal area (m^2 ha^{-1}), IVI- Important Value Index (%), A/F- distribution pattern ratio and H′- Shannon-Weiner diversity index, T- Hill top, M- Hill mid, B- Hill base

Table 3: One-way analysis of variance of different physic-chemical properties of soil in studied sacred forest

S. No.	Site	Location of hill	MC (%)	WHC (%)	pH	Average Carbon (%)	Average OM (%)	Nitrogen (%)	K (ppm)	P (ppm)
1	Kranteshwar	T	28.83 ± 0.17^{ab}	21.95 ± 0.24^{ef}	5.56 ± 0.03^{e}	0.82 ± 0.00^{c}	1.38 ± 0.02^{c}	0.88 ± 0.00^{a}	73.84 ± 0.6^{c}	0.50 ± 0.00^{c}
		M	17.36 ± 0.41^{de}	24.34 ± 0.37^{def}	6.63 ± 0.13^{bcd}	0.79 ± 0.00^{c}	1.42 ± 0.01^{b}	0.29 ± 0.01^{b}	87.13 ± 0.20^{b}	0.65 ± 0.00^{c}
		B	19.13 ± 0.34^{cde}	18.27 ± 0.68^{f}	5.53 ± 0.03^{e}	0.85 ± 0.00^{b}	1.42 ± 0.01^{b}	0.28 ± 0.01^{b}	84.08 ± 0.71^{b}	0.55 ± 0.00^{c}
2	Banlekh	T	26.30 ± 4.00^{abc}	26.28 ± 6.61^{de}	6.10 ± 0.35^{d}	0.48 ± 0.01^{ef}	0.80 ± 0.01^{e}	0.22 ± 0.07^{bc}	0.33 ± 0.07^{e}	19.47 ± 4.44^{ab}
		M	22.93 ± 0.40^{bcd}	28.10 ± 1.45^{de}	6.23 ± 0.23^{d}	0.47 ± 0.00^{f}	0.79 ± 0.00^{e}	0.09 ± 0.02^{d}	59.01 ± 4.45^{d}	12.53 ± 5.71^{b}
		B	25.16 ± 2.55^{abcd}	35.79 ± 2.69^{c}	5.40 ± 0.10^{e}	0.48 ± 0.01^{e}	0.81 ± 0.00^{e}	0.04 ± 0.01^{d}	59.18 ± 7.25^{d}	13.52 ± 2.46^{b}
3	GorakhNath	T	31.83 ± 1.90^{a}	31.49 ± 2.26^{cd}	6.50 ± 0.05^{cd}	0.59 ± 0.01^{d}	1.00 ± 0.00^{d}	0.22 ± 0.02^{bc}	82.22 ± 0.39^{b}	24.63 ± 7.88^{a}
		M	19.86 ± 2.82^{cde}	46.74 ± 3.10^{b}	5.53 ± 0.03^{e}	0.27 ± 0.01^{g}	0.43 ± 0.01^{g}	0.09 ± 0.02^{d}	64.22 ± 1.19^{d}	17.84 ± 2.24^{ab}
		B	28.26 ± 6.56^{ab}	60.16 ± 2.32^{a}	6.23 ± 0.37^{d}	0.98 ± 0.01^{a}	1.67 ± 0.01^{a}	0.13 ± 0.07^{cd}	1.12 ± 2.16^{a}	24.42 ± 0.62^{a}
4	Hingla Devi	T	17.50 ± 0.32^{de}	47.01 ± 0.12^{b}	7.10 ± 0.11^{ab}	0.30 ± 0.01^{g}	0.49 ± 0.01^{f}	0.05 ± 0.01^{d}	56.62 ± 0.03^{d}	14.13 ± 0.12^{ab}
		M	19.46 ± 0.26^{cde}	45.27 ± 0.13^{b}	7.00 ± 0.10^{abc}	0.27 ± 0.00^{g}	0.49 ± 0.00^{f}	0.06 ± 0.01^{d}	58.74 ± 0.03^{d}	9.55 ± 0.2^{bc}
		B	12.10 ± 0.15^{e}	57.51 ± 0.03^{a}	7.23 ± 0.06^{a}	0.26 ± 0.01^{g}	0.49 ± 0.00^{f}	0.13 ± 0.00^{cd}	57.53 ± 0.03^{d}	14.96 ± 0.04^{ab}

Note: MC- moisture content, WHC- water holding capacity, pH- hydrogen ion concentration, OM- organic matter, N- nitrogen, K- potassium, P-phosphorus, ppm- parts per million, T- Hill top, M- Hill mid, B- Hill base

Table 4: Pearson’s Correlation Coefficient among different variables

	Altitude	RDT	HT	RDS	HS	MC	WHC	pH	C	OM	N	K	P
Altitude	1.000												
RDT	-0.238	1.000											
HT	0.065	0.079	1.000										
RDS	0.238	-1.000**	-0.079	1.000									
HS	0.274	-0.951**	0.197	0.951**	1.000								
MC	-0.098	0.138	-0.585*	-0.138	-0.332	1.000							
WHC	-0.173	0.401	0.487	-0.401	-0.262	-0.275	1.000						
pH	0.335	0.033	0.708**	-0.033	0.163	-0.464	0.472	1.000					
C	-0.109	0.265	-0.544	-0.265	-0.42	0.469	-0.375	-0.402	1.000				

OM	-0.113	0.261	-0.514	-0.261	-0.407	0.435	-0.361	-0.356	0.997**	1.000			
N	0.261	-0.122	-0.549	0.122	-0.010	0.353	-0.529	-0.347	0.534	0.528	1.000		
K	0.103	0.065	0.172	-0.065	-0.037	-0.254	-0.429	-0.045	-0.025	-0.012	0.250	1.000	
P	-0.281	0.376	0.043	-0.376	-0.401	0.361	0.588*	0.178	-0.264	-0.28	-0.527	-0.594*	1.000

Note: *correlation is significant at the 0.05 level (2-tailed). **correlation is significant at the 0.01 level (2-tailed). RDT- tree relative density, HT- tree diversity index, RDS- sapling relative density, HS- sapling diversity index, MC- moisture content, WHC- water holding capacity, pH- hydrogen ion concentration, OM- organic matter, N- nitrogen, K- potassium, P- phosphorus

Conclusions

Present study suggests that the altitude doesn't always play an important role for the distribution of physical and chemical properties of soil, there might be some other responsible factors viz. aspect, slope, mode of conservation and forest forming species (early and late growing species). It is not always necessary that the vegetation is totally dependent on soil formation and altitude. In hilly regions of Kumaun Himalaya the mountain communities depend on community forests and reserved forests for fulfillment of their fodder, fuel-wood and other forest based requirements. On the other hand the sacred forests those are conserved through religious beliefs of communities are not open for collection of any forest produce for a varying period of time ranging from 5-20 years. Sacred forests face negligible anthropogenic pressure as compared to these reserved and community forests, hence, consists more richness of species and good forest composition and health. If the sacred forests are managed properly and the rules and regulations constituted for a particular sacred forest are strictly followed, these forests may play an important role in biodiversity conservation at local and regional levels.

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Compliance with ethical standards

The authors declare that they have no conflict of interest. This article does not contain any studies involving animals or human participants performed by any of the authors.

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