Physicochemical Properties of Soil under Different Forest Types in the Western Ramganga Valley (Uttarakhand Himalaya, India)

Dinesh Singh Rawat a,b*, Deep Shekhar Das c, Prabhawati Tiwari a*, Preeti Naithani a,d and Jay Krishan Tiwari a

a Department of Botany and Microbiology, HNB Garhwal University, Srinagar (Garhwal) - 246174, Uttarakhand, India.
b Department of Botany, Uttaranchal College of Science and Technology, Kulhan, Sahastradhara Road, Dehradun - 248001, Uttarakhand, India.
c Central National Herbarium, Botanical Survey of India, Howrah - 711103, West Bengal, India.
d Department of Botany, Doon (P.G.) College of Agriculture Science and Technology, Selaqui, Dehradun - 248007, Uttarakhand, India.

Authors’ contributions
This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The physicochemical properties of soils of six forests varying in elevation (lower, middle, and upper), slope, aspects, and floristic composition viz. L1 (Oak mixed), L2 (Chir pine), M1 (Rhododendron mixed), M2 (Rhododendron mixed), U1 (Abies mixed) and U2 (Abies mixed) from Western Ramganga Valley (Chamoli, Uttarakhand Himalaya, India) were scrutinized. The composite soil samples from three depths (0–10 cm, 11–20 cm, and 21–30 cm) were collected during the different seasons and the physicochemical parameters were analyzed using standard manual and protocol. Texture, bulk density, moisture content, water holding capacity, organic matter, organic carbon, pH, nitrogen content, available phosphorus, exchangeable potassium and C:N ratio of soil samples from each forest site were analyzed and discussed. It was observed that...
1. INTRODUCTION

Soil, the unconsolidated mineral material on the immediate surface of the earth [1–2], is one of the most important natural rudiments for forest vegetation as well as human civilization [3–4]. It is the dynamic, natural body whose development, nature, and structure vary considerably with geologic and geomorphologic factors (water, wind, temperature change, gravity, chemical interaction, topography, and pressure differences, aspect, slope angle), climate, and vegetation [5–7]. It serves as a loose surface material for the growth of land plants. Soil and vegetation are in a complex interrelationship since their togetherly development over a long period of time [8]. Soil improvises a major impact on the plant diversity of an ecosystem [9–10]. The type and rate of growth of plant species are mainly governed by mineral composition and nutrient supplying capability of the soil because plants mostly derived their nutrients from the available reserve minerals of the soil [11]. The mineral compositions of soils depend on the underlying rocks [12]. Vegetation on the other hand, influences the physicochemical properties of soil, helps in maintaining soil fertility by litter accumulation and decomposition, forms a shield for soil, and prevents soil erosion and improves infiltration rate, water holding capacity, hydraulic conductivity, and aeration [13].

Soil quality is a functional ability. Its variation in time and space is obvious and it influence different soil functions such as water redistribution, nutrient availability, and nutrient supply to plants [14–15]. Physicochemical features of forest soils vary according to the topography, climate, physical weathering processes, vegetation cover, microbial activities, and several other biotic variables [4,16]. These characteristics have major contributions in determining soil’s fitness for agricultural, environmental, engineering uses [17], and for determining the sites potentiality to support productive forests [18–19] for a better forest management practices.

Himalayan forests are well-known for their significant contributions in mitigating the disparity of the climate, in cooling and purifying the atmosphere, in soil safeguarding from erosion, in keeping the hill slopes in their natural position, and in maintaining the enormous reserves of soil nutrients [20]. Although, rapid deforestation in the Himalayan mountains mainly by the anthropogenic activities has vastly decreased the forest cover which ultimately leads to soil degradation by erosion processes [7,21]. This may also result in water logging which in turn may cause nutrient leaching and volatilization under the rhizosphere causing soil nutrient deficiency [22]. Consistent monitoring of soil quality of Himalayan forests is therefore of immense importance for the sustainability of natural forests and the environment.

The Indian Himalayan Region (IHR), one of the global biodiversity hotspots [23] expands from Kashmir at the west to Arunachal Pradesh at the east. The IHR is broadly divided into two parts, viz. Eastern Himalaya and Western Himalaya are separated by the Central Himalaya (Nepal). Due to its vast geographical extends, the Western Himalaya shows huge variations in the climatic conditions, topography, and soil characteristics and forms a very complex ecosystem [24–26]. The present study has been carried out in the Western Ramganga Valley of Uttarakhand, Western Himalaya. A few studies are available on the soil physicochemical properties from different forests of Uttarakhand Himalaya [27–36]. But, the reports on the physicochemical
properties of soil from Western Ramganga Valley are unavailable hitherto. On this background, the present study is designed to understand physicochemical properties of soil under different forest types of Western Ramganga Valley of Uttarakhand in the Western Himalaya in India.

2. MATERIALS AND METHODS

2.1 Study Area

The study has been conducted at six forest sites with diverse ecosystems and environmental factors in the Western Ramganga Valley in Uttarakhand. The study area is located in the southern part of the district Chamoli (bordering to district Almora and Pauri) between 29°57′33″N to 30°06′05″N latitudes and 79°11′33″E to 79°20′33″E longitudes with elevation range 1200–3100 m asl. The area is characterized by a temperate climate with well-marked summer, rainy, and winter seasons. The temperature reaches a maximum during May–June and minimum amid December–January. The maximum annual rainfall takes place in July–August, and minimum during November–December. The floral wealth of the area mainly consists of sub-montane and montane Himalayan plants. More than 650 flowering plants species are known from the Western Ramganga Valley [37–38] including 254 fodder yielding [39], 140 ethnomedicinal, and 82 wild edible resources [40–41]. The broad-leaved forest dominates in the area followed by Abies pindrow mixed forests towards ridge tops and Pinus roxburghii mixed forests at lower elevations [42]. The forests are intact at higher elevations and along the river valleys, while disjunctive at lower elevations due to agricultural encroachment and human habitation. The heavy exploitation of easily accessible forest area (adjacent to villages and seasonal Dhabas) has converted and is still converting into scrubs or bushy secondary growth.

To investigate the physicochemical properties of soils, six forest sites have been selected at three elevations viz. lower (L1, L2), middle (M1, M2), and upper (U1, U2) (Table 1). Sites L1, M1, and U1 fall at the right flank of the Ramganga river, whereas L2, M2, and U2 on the left flank.

2.2 Sampling

Field surveys have been conducted in summer (May), rainy (August), and winter (December) seasons of the years 2018 and 2019 to collect soil samples and field data. A total of ten sampling plots of size 400 m² of area have been established in each site by walking uphill along a crisscross trail of ca. 3.5 to 4 km length, with a minimum of 250 m distance between the plots. Composite soil samples have been collected from each plot from three depths (0–10 cm, 11–20 cm, 21–30 cm) using a soil auger. Then, depth wise homogenized composite soil samples have been prepared by mixing two samples from corners and one from center of each plot. The samples have been packed in the air tight polythene bags for physicochemical analysis.

2.3 Physicochemical Analysis

The texture of soil samples was determined by measuring the relative portion of sand, silt, and clay using sieves of different pore sizes. The bulk density was calculated using a special metallic core-sampling cylinder of known volume [43]. Moisture content was estimated by measuring the difference of fresh weight and oven-dried weight of soil samples [44]. Water holding capacity was estimated through water retaining capacity of water saturated soil samples [45]. Soil pH was measured with digital pH meter. Total nitrogen (%) was measured through the Kjeldahl method [46]. The available phosphorus was estimated following Olsen et al. [47] while exchangeable potassium was estimated following Morwin and Peach [48]. The organic carbon content (%) was estimated following Nelson and Sommers [49]. Tentative soil organic matter (%) was calculated by using Van Bemmelen conversion factor (=1.724). The physical analysis of soil samples were performed in the Laboratory of Ecology (Department of Botany & Microbiology, HNB Garhwal University, Srinagar Garhwal, Uttarakhand). Chemical analyses were conducted at the Regional Soil Testing Laboratory (Srinagar Garhwal, Uttarakhand) and at the Indian Institute of Soil and Water Conservation (Dehradun, Uttarakhand).

2.4 Statistical Analysis

The relationships between the soil physicochemical parameters were determined using bivariate Pearson correlation analysis. ANOVA was applied to test the level of statistical differences in various soil physicochemical parameters across the six forests. Both, Pearson correlation and ANOVA were calculated using IBM SPSS, version 23 while basic statistical analysis was performed using MS Excel.
3. RESULTS AND DISCUSSION

3.1 Soil Physical Properties

Soil texture

The soil texture has a great influence on the development of soil aggregates [7]. In the present study, mean value of sand varies from 32.07±1.33% (L2) to 65.29±0.58% (U2), silt from 19.83±0.27% (U2) to 44.61±1.42% (L2) and clay 5.05±0.90% (M1) to 23.31±1.18% (L2) (Table 2). Statistically significant difference was observed in the composition of soil i.e. sand (F₅,₁₂ = 891.27, p=0.00), silt (F₅,₁₂ = 296.79, p=0.00) and clay (F₅,₁₂ = 189.30, p=0.00) of different forest sites. The maximum percentage of sand, silt, and clay for the upper layer was 66.56±1.35%, 43.11±2.21%, and 23.44±1.43% respectively, while the minimum was 33.45±2.65%, 19.53±3.23% and 4.09±1.33% respectively. The percentage of sand, silt, and clay for the middle layer varies from 31.98±2.05 to 65.97±0.97, 19.91±2.32 to 45.94±2.67, and 5.88±1.67 to 22.08±1.12 respectively, and for the lower layer varies from 30.79±1.56 to 65.91±4.23, 20.05±3.00 to 44.79±3.11 and 5.03±0.90 to 24.42±0.94 respectively.

Texturally, the studied soils are loam at L2 and U1 sites, while sandy loam at L1, M1, M2, and U2 sites. Our findings are comparable to reports from other Western Himalayan forests by Mahajan et al. [3], Arya [35], Chawla et al. [50], and Prakash [51]. The soil texture has more or less a static property affecting almost other ones [17]. This texture has a huge role in porosity and pore size distribution in soil. The coarse-textured soils are known to have lower total porosity than the fine-textured soils, while the clayey soils exhibit highly variable porosity as swelling, shrinkage, aggregation, dispersion, compaction and cracking occurs upon wetting and drying [17]. Tete-Mensah [52] explained that the soils with loose particles like sand result in a single grain structure and helps in plant growth, while the clayey-rich soils with fine-grained particles usually become impermeable for water and hamper penetration of plant roots. Izwaida et al. [53] observed that clay plays a major role in the organic matter formation and enriches capacity of soil to retain the nutrients level of the soil.

Bulk density

The average soil bulk density in the study area is ranged from 0.75±0.07 (L2) to 1.21±0.14 g cm⁻³ (M1) (F₅,₁₂ = 5.43, p=0.08). In the upper layer, it varies from 0.68±0.11 to 1.05±0.57 g cm⁻³; from 0.76±0.23–1.25±0.41 g cm⁻³ in the middle layers; and from 0.82±0.33 to 1.33±0.87 g cm⁻³ in the lower layers (Table 3). The bulk density is of great importance in understanding the physical behavior of soils. It depends on soil texture, structure, moisture content, organic matter, freezing, and thawing processes [54–55]. Generally, bulk density decreases with increasing organic matter content and fineness of soil texture [17]. Our findings are comparable to those of Mahajan et al. [3] and Ballabh [21] from Western Himalaya.

Moisture content

Soil moisture content (MC) is very effective in expressing the soil consistency which is the resistance of soil to deformation or rupture under applied pressure [17]. The soils remain hard at low moisture and become soft with an increase in moisture content. Our results revealed that the average moisture content of the soil at different study sites ranged from 12.79±0.47 to 18.25±0.22% (F₅,₁₂ = 27.36, p=0.00). It varies from 13.09±1.59 to 18.23±2.67%, 13.02±2.17 to 18.48±3.03% and 12.25±2.03 to 18.04±3.11% for upper, middle and lower layers respectively (Table 3). Soil moisture content is an important attribute for vegetation development. Variations in soil moisture content may substantially change tree species diversity and forest canopy structure [56]. It is a well-known fact that the Western Himalaya is much drier than the other parts of the Himalaya. Likewise, the present report indicates low moisture retention ability by the soil in the study area. The observed values are comparable to those of Prakash [51] and Joshi et al. [57] from Western Himalaya. The difference in MC in various forest soils is may be due to the abiotic factors (e.g. elevation, rainfall, forest cover, aspect and slope of the forests, water holding capacity of the soil) and excessive moisture absorbing essence of a few trees as Quercus spp. [19].

Water holding capacity

The water holding capacity (WHC) of soil is largely a function of soil capillary and pores [58]. It gives reasonable information about the capacity of soil to retain water [59]. It powers the plant growth, rooting pattern, and ability to supply water to plants during the dry periods [60]. The average water holding capacity of soil samples in the study area ranged from 53.29±3.82% (M1) to

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3.2 Soil Chemical Properties

Soil Organic Carbon

The maximum available phosphorus content of the soil at various study sites ranges between 25.61 kg ha\(^{-1}\) (U1) and 33.0 kg ha\(^{-1}\) (U2), while the average value is 29.83±2.93 kg ha\(^{-1}\) (F\(_{5}, 12\) =1.38, p=0.29). Maximum phosphorus for upper, middle, and lower layers is recorded as 32.856±0.09 kg ha\(^{-1}\) (L1), 34.4±4.19 kg ha\(^{-1}\) (M1), and 38.48±3.67 kg ha\(^{-1}\) (M1) respectively. While minimum phosphorus content for upper, middle, and lower layers is found as 20.654±2.80 kg ha\(^{-1}\) (U1), 24.208±3.67 kg ha\(^{-1}\) (U1), and 24.568±1.87 kg ha\(^{-1}\) (L1) respectively (Table 5). The recorded values from the present study are in parity with Gairola et al. [71] for Mandal–Chopta in Chamoli (Western Himalaya). Similar results have also been reported by Mahajan et al. [3].
The overall mean value of potassium content of the soil of different study sites is recorded as 221.22±21.79 kg ha⁻¹ (F₅,₁₂ =1.37, p=0.30). Maximum potassium content is found at L2 (247.52 kg ha⁻¹) while minimum potassium content is recorded from U2 (184.05 kg ha⁻¹). It ranges from 183.68±10.08 to 368.8±33.55 kg ha⁻¹ for the upper layers, 174.72±10.69 to 264.32±33.89 kg ha⁻¹ for the middle layers, and 184.8±35.98 to 271.04±32.44 kg ha⁻¹ for the lower layers of soil (Table 5). This finding agrees with that of Mahajan et al. [3], Mehta et al. [63], Gairola et al. [71], and Bahuguna et al. [73] from Western Himalaya.

The high values of total nitrogen (N), available phosphorus (P) and exchangeable potassium (K) may be ascribed to high organic matter content in the soil [74]. This could also be attributed to their occurrence in organic matter combination with organic carbon [62]. Another probability of high N, P, and K concentration in soils is that the study area is composed of loam to sandy loam which are acidic in nature. Rathore [75] studied the area and reported that soils with sandstones and soils which are acidic in nature. Rathore [75] has earlier reported that soils with sandstones and acidic nature are usually rich in organic matter and nitrogen. C:N ratio

The C:N ratio is the major index of the fertility of organic manures and varies depending upon the source and stage of decomposition of the litter. The C:N ratio of soil in the present study at different sites ranged between 7.64 and 13.18 (F₅,₁₂ =1.19, p=0.36). Maximum C:N ratio for upper, middle, and lower layer was recorded as 20.93 (U2), 14.27 (M2), and 11.88 (U1) respectively, while the minimum value of C:N ratio was recorded as 5.58 (L1) for the upper layer, 5.67 (U2) for the middle, and 7.50 (M1) for lower layer (Table 5). This report agrees with Nazir [66], Gairola et al. [71], and Thadani and Ashton [76].

3.3 Correlation

Correlation analysis between various physicochemical properties of soil (Table 6) reveals that the pH is negatively correlated with moisture content (r=-0.836, p<0.0175), bulk density (r=-0.323, p=0.533), and C:N ratio (r=-0.225, p=0.668). WHC has significant positive correlation with C:N ratio (r=0.846, p=0.034), while negative relation with moisture content (r=-0.595, p=0.213), available phosphorus (r=0.314, p=0.544), SOC (r=0.978, p=0.001) and

Table 1. Detail of the six study sites in the western Ramganga Valley, Uttarakhand

| Study sites | Name of forest | Elevation (m asl) | Tree density (ha⁻¹)** | Dominant tree species (Local name) |
|-------------|----------------|------------------|-----------------------|-----------------------------------|
| L1          | Kulagar-Dungari| 1400–2000        | 1170                  | Quercus oblongata (Banj), Myrica esculenta (Kafaw), Rhododendron arboreum (Burans) |
| L2          | Khakra-Siyoni  | 1350–2250        | 840                   | Pinus roxburghii (Kuyu, Chir), Rhododendron arboreum (Burans), Quercus oblongata (Banj) |
| M1          | Adrapa-Matkot  | 1800–2300        | 1140                  | Rhododendron arboreum (Burans), Quercus floribunda (Burans), Rhododendron arboreum (Burans), Quercus floribunda (Tyuj), Quercus oblongata (Banj) |
| M2          | Deopuri-Angyari| 1800–2300        | 570                   | Rhododendron arboreum (Burans), Quercus floribunda (Tyuj), Quercus oblongata (Banj) |
| U1          | Kodiyabagarh-Kothki | 2500–3000    | 830                   | Abies pindrow (Rainsaw), Quercus semecarpifolia (Khair), Quercus floribunda (Tyuj) |
| U2          | Bakharkhet-Chorani | 2100–2700  | 540                   | Abies pindrow (Rainsaw), Quercus semecarpifolia (Khair), Quercus floribunda (Tyuj) |

Abbreviations: L1 & L2 = lower montane, M1 & M2= middle montane, U1 & U2= upper montane, 1 indicative of right flanks of Western Ramganga river and 2 left flank; **Rawat et al. [42]
Table 2. Soil texture at different sites in the western Ramganga Valley, Uttarakhand (Mean±SD)

| Site | Depth (cm) | Sand (%) | Silt (%) | Clay (%) | Texture class |
|------|------------|----------|----------|----------|---------------|
| L1   | 0-10       | 50.57±2.67 | 30.61±0.96 | 18.82±0.45 | Sandy loam |
|      | 11-20      | 49.81±1.79 | 29.82±0.54 | 20.37±0.78 | Sandy loam |
|      | 21-30      | 49.54±1.33 | 30.02±0.37 | 20.44±0.91 | Sandy loam |
|      | Mean±S.D.  | 49.97±0.53 | 30.15±0.41 | 19.88±0.92 | Sandy loam |
| L2   | 0-10       | 33.45±2.65 | 43.11±2.21 | 23.44±1.43 | Loam         |
|      | 11-20      | 31.98±2.05 | 45.94±2.67 | 22.08±1.12 | Loam         |
|      | 21-30      | 30.79±1.56 | 44.79±3.11 | 24.42±0.94 | Loam         |
|      | Mean±S.D.  | 32.07±1.33 | 44.61±1.42 | 23.31±1.18 | Loam         |
| M1   | 0-10       | 65.56±1.35 | 30.35±1.04 | 4.09±1.33  | Sandy loam   |
|      | 11-20      | 65.97±0.97 | 28.15±1.43 | 5.88±1.67  | Sandy loam   |
|      | 21-30      | 64.51±1.56 | 30.46±0.97 | 5.03±0.90  | Sandy loam   |
|      | Mean±S.D.  | 65.35±0.75 | 29.65±1.30 | 5.00±0.90  | Sandy loam   |
| M2   | 0-10       | 50.56±4.33 | 40.35±2.53 | 9.09±0.93  | Sandy loam   |
|      | 11-20      | 51.19±4.83 | 39.73±2.11 | 9.08±0.56  | Sandy loam   |
|      | 21-30      | 51.51±3.67 | 40.46±3.08 | 8.03±0.76  | Sandy loam   |
|      | Mean±S.D.  | 51.09±0.48 | 40.18±0.39 | 8.73±0.61  | Sandy loam   |
| U1   | 0-10       | 45.87±1.60 | 34.32±1.66 | 19.81±0.78 | Loam         |
|      | 11-20      | 46.01±2.38 | 35.77±1.48 | 18.22±0.69 | Loam         |
|      | 21-30      | 45.91±2.54 | 35.02±1.11 | 19.07±0.99 | Loam         |
|      | Mean±S.D.  | 45.93±0.07 | 35.04±0.73 | 19.03±0.80 | Loam         |
| U2   | 0-10       | 64.76±5.43 | 19.53±3.23 | 15.71±1.89 | Sandy loam   |
|      | 11-20      | 65.21±5.32 | 19.91±2.32 | 14.88±1.48 | Sandy loam   |
|      | 21-30      | 65.91±4.23 | 20.05±3.00 | 14.04±1.98 | Sandy loam   |
|      | Mean±S.D.  | 65.29±0.58 | 19.83±0.27 | 14.88±0.84 | Sandy loam   |

Table 3. Bulk density, Moisture content, and WHC of soils of the study area

| Site | Depth (cm) | Bulk density (g cm⁻³) | Moisture (%) | WHC (%) |
|------|------------|-----------------------|--------------|---------|
| L1   | 0-10       | 0.89±0.22             | 15.67±2.43   | 67.33±2.11 |
|      | 11-20      | 1.07±0.56             | 15.33±2.09   | 64.60±2.28 |
|      | 21-30      | 1.24±0.16             | 14.21±1.54   | 63.03±2.91 |
|      | Mean±S.D.  | 1.07±0.18             | 15.07±0.76   | 64.99±2.18 |
| L2   | 0-10       | 0.66±0.11             | 13.09±1.59   | 73.65±3.79 |
|      | 11-20      | 0.76±0.23             | 13.02±2.17   | 70.12±3.69 |
|      | 21-30      | 0.82±0.33             | 12.25±2.03   | 68.81±2.54 |
|      | Mean±S.D.  | 0.75±0.07             | 12.79±0.47   | 70.86±2.50 |
| M1   | 0-10       | 1.05±0.57             | 17.92±3.21   | 57.09±3.04 |
|      | 11-20      | 1.25±0.41             | 17.21±3.33   | 53.32±3.37 |
|      | 21-30      | 1.33±0.87             | 16.05±1.59   | 49.45±3.67 |
|      | Mean±S.D.  | 1.21±0.14             | 17.06±0.94   | 53.29±3.82 |
| M    | 0-10       | 0.84±0.51             | 18.23±2.67   | 56.39±4.54 |
|      | 11-20      | 0.91±0.34             | 18.48±3.03   | 54.66±3.00 |
|      | 21-30      | 0.98±0.65             | 18.04±3.11   | 51.16±2.87 |
|      | Mean±S.D.  | 0.91±0.07             | 18.25±0.22   | 54.07±2.66 |
| U1   | 0-10       | 0.75±0.21             | 17.78±2.33   | 72.17±3.67 |
|      | 11-20      | 0.86±0.55             | 17.08±2.02   | 69.53±4.33 |
|      | 21-30      | 0.92±0.61             | 17.87±2.79   | 68.07±3.70 |
|      | Mean±S.D.  | 0.84±0.09             | 17.58±0.43   | 69.92±2.08 |
| U2   | 0-10       | 0.88±0.70             | 17.07±3.01   | 67.33±3.21 |
|      | 11-20      | 1.04±0.11             | 16.98±2.53   | 65.91±2.09 |
|      | 21-30      | 1.18±0.43             | 15.59±1.59   | 62.67±3.59 |
|      | Mean±S.D.  | 1.03±0.15             | 16.55±0.83   | 65.30±2.39 |
Table 4. Soil pH, SOC and SOM, at different sites in the study area

| Site | Depth (cm) | pH   | SOC (kg ha⁻¹) | SOM (%) |
|------|------------|------|---------------|---------|
| L1   | 0-10       | 4.8±0.07 | 0.435±0.11 | 0.752±0.12 |
|      | 11-20      | 4.7±0.04 | 0.780±0.13 | 1.34±0.72 |
|      | 21-30      | 5.4±0.05 | 0.750±0.11 | 1.29±0.93 |
|      | Mean±S.D.  | 4.97±0.38 | 0.66±0.19 | 1.13±0.33 |
| L2   | 0-10       | 5.2±0.03 | 0.585±0.15 | 1.01±0.54 |
|      | 11-20      | 5.4±0.05 | 0.825±0.14 | 1.42±0.23 |
|      | 21-30      | 5.9±0.03 | 0.726±0.12 | 1.25±0.16 |
|      | Mean±S.D.  | 5.5±0.36 | 0.71±0.12 | 1.23±0.21 |
| M1   | 0-10       | 5.1±0.08 | 0.735±0.10 | 1.26±0.14 |
|      | 11-20      | 5.2±0.07 | 0.570±0.09 | 0.98±0.26 |
|      | 21-30      | 4.7±0.06 | 0.525±0.12 | 0.90±0.51 |
|      | Mean±S.D.  | 5±0.26   | 0.61±0.11 | 1.05±0.19 |
| M2   | 0-10       | 5.3±0.10 | 0.585±0.16 | 1.01±0.84 |
|      | 11-20      | 5.1±0.09 | 0.585±0.14 | 1.01±0.19 |
|      | 21-30      | 5.0±0.07 | 0.435±0.10 | 0.75±0.35 |
|      | Mean±S.D.  | 5.13±0.15 | 0.54±0.09 | 0.92±0.15 |
| U1   | 0-10       | 5.0±0.08 | 0.450±0.14 | 0.78±0.58 |
|      | 11-20      | 4.6±0.10 | 0.675±0.12 | 1.16±0.37 |
|      | 21-30      | 4.9±0.06 | 0.570±0.11 | 0.98±0.15 |
|      | Mean±S.D.  | 4.83±0.21 | 0.57±0.11 | 0.97±0.19 |
| U2   | 0-10       | 5.3±0.03 | 0.90±0.09  | 1.55±0.16 |
|      | 11-20      | 5.0±0.05 | 0.255±0.12 | 0.44±0.55 |
|      | 21-30      | 5.5±0.40 | 0.510±0.09 | 0.88±0.33 |
|      | Mean±S.D.  | 5.27±0.25 | 0.56±0.32 | 0.96±0.31 |

Table 5. NPK and C:N of soils of the study area

| Site | Depth (cm) | N (%) | P (kg ha⁻¹) | K (kg ha⁻¹) | C:N |
|------|------------|-------|-------------|-------------|-----|
| L1   | 0-10       | 0.078 | 32.56±2.08  | 259.84±15.78 | 5.58 |
|      | 11-20      | 0.081 | 29.60±3.99  | 219.52±21.90 | 9.63 |
|      | 21-30      | 0.084 | 24.56±1.87  | 230.72±19.67 | 8.93 |
|      | Mean±S.D.  | 0.081±0.003 | 28.91±4.04 | 236.69±20.81 | 8.05 |
| L2   | 0-10       | 0.095 | 29.00±8.09  | 207.20±30.80 | 6.16 |
|      | 11-20      | 0.093 | 28.416±1.33 | 264.32±33.89 | 8.87 |
|      | 21-30      | 0.092 | 25.45±1.18  | 271.04±32.44 | 7.89 |
|      | Mean±S.D.  | 0.093±0.003 | 27.63±0.190 | 247.52±35.08 | 7.64 |
| M1   | 0-10       | 0.059 | 24.80±3.31  | 208.32±28.50 | 12.46 |
|      | 11-20      | 0.062 | 34.40±4.19  | 196.00±31.80 | 9.19 |
|      | 21-30      | 0.070 | 38.48±3.67  | 257.60±32.69 | 7.50 |
|      | Mean±S.D.  | 0.064±0.007 | 32.56±7.02 | 220.64±32.60 | 9.72 |
| M2   | 0-10       | 0.038 | 31.08±1.25  | 192.96±31.48 | 15.39 |
|      | 11-20      | 0.041 | 28.712±1.15 | 264.32±44.80 | 14.27 |
|      | 21-30      | 0.044 | 34.15±2.10  | 184.80±35.98 | 9.89 |
|      | Mean±S.D.  | 0.041±0.003 | 31.31±2.73 | 214.03±43.7 | 13.18 |
| U1   | 0-10       | 0.045 | 20.65±2.80  | 268.80±33.55 | 10.00 |
|      | 11-20      | 0.048 | 24.20±3.67  | 197.12±37.39 | 14.06 |
|      | 21-30      | 0.048 | 31.96±8.13  | 207.20±36.41 | 11.88 |
|      | Mean±S.D.  | 0.047±0.001 | 25.61±5.79 | 224.37±38.80 | 11.98 |
| U2   | 0-10       | 0.043 | 32.85±6.09  | 183.68±10.08 | 20.93 |
|      | 11-20      | 0.045 | 31.67±1.88  | 174.72±10.69 | 5.67 |
|      | 21-30      | 0.046 | 34.33±2.56  | 193.76±12.08 | 11.09 |
|      | Mean±S.D.  | 0.045±0.001 | 32.95±1.33 | 184.05±9.53 | 12.56 |
The attributes are intimately linked with soil properties, chiefly because all these attributes are intimately linked with soil humus and SOM (r=−0.943, p=0.005). The soil bulk density shows a weak positive correlation with WHC while negative correlation with soil moisture content. Sharma et al. [20] reported negative correlation of soil bulk density with moisture content and WHC. Soil Nitrogen content is positively correlated with SOC (r=0.958, p=0.003) and SOM (r=0.994, p=0.00), and shows negative correlation with phosphorus (r=−0.325, p=0.53) and C:N ratio (r=−0.983, p=0.00). Gairola et al. [71] also reported positive correlation of nitrogen with SOC and SOM, and negative correlation with C:N ratio. Available phosphorus shows negative correlation with potassium (r=−0.673, p=0.143), SOC (r=−0.257, p=0.623) and SOM (r=−0.351, p=0.496). Significant positive correlation is found between SOC and SOM (r=0.972, p=0.001). Ballabha [21] have reported positive correlation of moisture content with WHC, bulk density, nitrogen and SOC; WHC with bulk density, nitrogen, SOC; and nitrogen with SOC while negative correlation of C:N ratio with almost all physicochemical properties of soil from Alaknanda Valley, Western Himalaya. The carbon-phosphorus and nitrogen-phosphorus ratio vary according to the parent material, which depend upon degree of weathering and by other means [77]. Soil N and K were positively correlated chiefly because all these attributes are intimately linked with soil humus [78].

### 4. CONCLUSION

The physicochemical properties of soil are predominantly important in determining the ability of the soil for root saturation, air and water movement, and uptake of water by plants [79–80]. Soil physical and chemical properties mostly influence the extent of the decomposition process. Thus, the forest reserve serves as protection for the soil and promotes the fertility and productivity of the soils to support a thriving vegetation types in a particular area. In the present study, soil texture is either loam or sandy loam which is very supportive for plant growth. The lower bulk density and higher soil organic carbon (SOC) and organic matter (SOM) with other determined parameters in the studied soils indicated that the soils are with considerable nutrients. Moreover, near to optimum water holding capacity and soil moisture, moderate acidic nature, and high NPK content of soil also indicate the presence of good productive soil in the study area. However, this study is only limited to assessing the physicochemical properties of soil of Western Ramganga Valley, carried out to fill the knowledge gap of soil characteristics of the said area. To ascertain interrelationship among the vegetation and soils of Western Ramganga Valley further elaborative study is needed.
ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Jackson ML. Soil chemical analysis. Prentice Hall of India Private Limited, New Delhi; 1967.
2. Donahue RL, Miller RW, Schickluna JC. An introduction to soil and plant growth, 5th edition. Prentice Hall of India Pvt. Ltd., New Delhi, India; 1987.
3. Mahajan A, Sharma SK, Gupta RD, Sharma R. Morphological, physical and chemical properties of soils from north west Himalayas. Bulgarian Journal of Agricultural Science. 2007;13(5):607–618.
4. Singh D. Phytodiversity, forest structure and composition in the montane zone of Western Ramganga Valley, Uttarakhand Himalaya. Ph.D. Thesis, HNB Garhwal University Srinagar (Garhwal), Uttarakhand, India; 2016.
5. Saxena HO, Srivastava PBL. Forest communities of Mussoorie. Tropical Ecology. 1973;14(2):197–218.
6. Sharma CM, Baduni NP, Gairola S, Ghildiyal SK, Suyal S. The effect of slope aspects on forest compositions, community structures and soil properties in natural temperate forests in Garhwal Himalaya. Journal of Forestry Research. 2010a;21(3):331–337. Available:https://doi.org/10.1007/s11676-010-0079-y
7. Opeyemi AO, Adewunmi BI, Oluwaseyi Al. Physical and chemical properties of soils in Gambari Forest Reserve Near Ibadan, South Western Nigeria. Journal of Bioresource Management. 2020;7(2):57–67. Available:https://doi.org/10.35691/jbm.020 2.0132
8. Champan JL, Reiss MJ. Ecology principals and application. Cambridge University, UK; 1992.
9. Rawat DS, Tiwari P, Das SK, Tiwari JK. Tree species composition and diversity in montane forests of Garhwal Himalaya in relation to environmental and soil properties. Journal of Mountain Science. 2020;17(12):3097–3111. Available:https://doi.org/10.1007/s11629-019-5761-8
10. Thakur U, Bisht NS. Physicochemical properties of soil in a protected area network (Chur peak): Churdhar Wildlife Sanctuary in Western Himalaya. Plant Archives. 2020;20(2):7533–7542.
11. Steila D. The Geography of soils: Formation, distribution and management. Englewood Cliffs, Prentice-Hall; 1976.
12. Raina AK, Gupta MK. Soil and vegetation studies in relation to parent material of Garhwal Himalayas, Uttarakhand (India). Annals of Forestry. 2009;17(1):71–82.
13. Eni DD, Iwara AI, Offiong RA. Analysis of soil vegetation interrelationships in a south-southern secondary forest of Nigeria. International Journal of Forestry Research. 2012;2012:469326(1–8). Available:https://doi.org/10.1155/2012/469326
14. Shukla MK, Lal R, Ebinger M. Soil quality indicators for reclaimed mine soils in south eastern Ohio. Soil Science. 2004;169:133–142. Available:https://dx.doi.org/10.1097/01.ss.0 000117785.98510.0f
15. Adhikari P, Shukla MK, Mexal JG, Sharma P. Assessment of the soil physical and chemical properties of desert soils irrigated with treated wastewater using principal component analysis. Soil Science. 2011;176(7):356–366. Available:https://doi.org/10.1097/SS.0b013 e31821fa4a72
16. Saha S, Rajwar GS, Kumar M. Soil properties along altitudinal gradient in Himalayan temperate forest of Garhwal region. Acta Ecologica Sinica. 2018;38(1):1–8. Available:https://doi.org/10.1016/j.chnaes.2 017.02.003
17. Phogat VK, Tomar VS, Dahyia R. Soil physical properties. In: Rattan RK, Katyal JC, Dwivedi BS, Sarkar AK, Bhattachatyya T, Tarafdar JC, Kukal SS (eds), Soil Science: An Introduction. Indian Society of Soil Science, New Delhi; 2015;135–171.
18. Kumar M, Sharma CM, Rajwar GS. Physicochemical properties of forest soil along altitudinal gradient in Garhwal Himalaya. Journal of Hill Research. 2004;17(2):60–64.
19. Malik ZA, Haq SM, Bussmann RW, Bhatt JA, Bhatt AB. Altitudinal variation in soil properties with reference to forest structure and composition in western Himalaya. Indian Forester. 2021;147(3):288–301.

20. Sharma CM, Gairola S, Ghildiyal SK, Suyal S. Physical properties of soils in relation to forest composition in moist temperate valley slopes of the Central Western Himalaya. Journal of Forest and Environmental Science. 2010b;26(2):117–129.

21. Ballabha R. Floristic diversity and quantitative features of vegetation around alakananda river: A case study of the srinagar hydroelectric power project in Garhwal Himalaya. Ph. D. thesis, HNB Garhwal University, Srinagar Garhwal, India; 2011.

22. Olujobi OJ. Comparative effect of selected tree legumes on physicochemical properties of an alfisol in Ekiti State. ARPN Journal of Agricultural and Biological Science. 2016;11(3):82–87.

23. Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J. Biodiversity hotspots for conservation priorities. Nature. 2000;403:853–858. Available:https://doi.org/10.1038/35002501

24. Singh P, Dash SS, Sinha BK. Plants of Indian Himalayan Region (An Annotated Checklist & Pictorial Guide), Part - I. Botanical Survey of India, Kolkata, India; 2019.

25. Das DS, Rawat DS, Maity D, Dash SS, Sinha BK. Species richness patterns of different life-forms along altitudinal gradients in the Great Himalayan National Park, Western Himalaya, India. Taiwania. 2020;65(2):154–162.

26. Dash SS, Panday S, Rawat DS, Kumar V, Lahiri S, Sinha BK, Singh P. Quantitative assessment of vegetation layers in tropical evergreen forests of Arunachal Pradesh, Eastern Himalaya, India. Current Science. 2021;120(5):850–858.

27. Tiwari SC, Gupta SK. Grassland ecology of Garhwal Himalaya with special reference to microclimate and phytosociology. In: Pliwal GS (ed.), The Vegetational Wealth of the Himalaya. Pooja Publishers, Delhi, India; 1982.

28. Singhal RM, Sharma SD. Study of the soils of Doon Valley forests. Journal of the Indian Society of Soil Science. 1985;33(3):627–634.

29. Bhandari BS, Mehta JP, Tiwari SC. Dominance and diversity relations of woody vegetation structure along an altitudinal gradient in a montane forest of Garhwal Himalaya. Journal of Tropical Forest Science. 2000;12(1):49–61.

30. Khanduri VP, Sharma CM, Ghildiyal SK, Puspwan KS. Forest composition in relation to socioeconomic status of people at three high altitudinal villages of a part of Garhwal Himalayas. Indian Forester. 2002;128(12):1335–1345.

31. Rawat RS. Studies on interrelationship of woody vegetation density and soil characteristics along altitudinal gradient in a montane forest of Garhwal Himalayas. Indian Forester. 2005;131(8):990–994.

32. Bargali K, Usman S, Joshi M. Effect of forest covers on certain site and soil characteristics in Kumaon Himalaya. Indian Journal of Forestry. 1998;21(3):224–227.

33. Verma TP, Singh SP, Rathore TR. Effect of slope aspects and altitude on some soil characteristics in Garhwal Himalayas. Journal of the Indian Society of Soil Sciences. 2008;56(1):42–48.

34. Jina BS, Bohra CS, Lodhiyal LS, Sah P. Soil characteristics in oak and pine forests of Indian Central Himalaya. E-International Scientific Research Journal. 2011;3(1):19–22.

35. Arya MK. Assessment of physicochemical properties of soil along altitudinal gradients in a protected forest in the Kumaun Himalayas, India. Nature and Science. 2014;12(2):32–37.

36. Saleem S, Kumar M. Species composition, distribution pattern and soil properties in influenced zone of Srinagar hydroelectric project of Garhwal Himalaya, India. Forest Research: Open Access. 2015;4(1):137. Available:https://doi.org/10.4172/21689776.1000137

37. Rawat DS, Tiwari JK, Tiwari P, Singh H. Floristic diversity of montane zone of western Ramganga Valley, Uttarakhand, India. Journal of Economic and Taxonomic Botany. 2016;40(3-4):104–125.

38. Rawat DS, Bagri AS, Parveen M, Nautiyal M, Tiwari P, Tiwari JK. Pattern of species richness and floristic spectrum along the elevation gradient: a case study from western Himalaya, India. Acta Ecologica Sinica; 2021. Available:https://doi.org/10.1016/j.chnaes.2021.03.012
39. Rawat DS, Tiwari JK, Uniyal PL, Tiwari P. Assessment of fodder species in western Ramganga Valley, Uttarakhand, India. International Journal of Tropical Agriculture. 2018a;36(1):23–36.

40. Ballabha R, Singh D, Tiwari JK, Tiwari P. Diversity and availability status of ethno-medicinal plants in the Lohba range of Kedarnath Forest Division (KFD), Garhwal Himalaya. Global Journal of Research on Medicinal Plants & Indigenous Medicine. 2013a;2(4):198–112.

41. Ballabha R, Singh D, Tiwari JK, Tiwari P, Gairola A. Wild edible plant resources of the Lohba range of Kedarnath forest division (KFD), Garhwal Himalaya, India. Indian Research Journal of Biological Sciences. 2013b;2(11):65–73.

42. Rawat DS, Tiwari JK, Tiwari P, Nautiyal M, Parveen M, Singh N. Tree species richness, dominance and regeneration status in western Ramganga Valley, Uttarakhand Himalaya, India. Indian Forester. 2018b;144(7):595–603.

43. Misra R. Ecology Workbook. Oxford and IBH Publication Company, Culcutta, India; 1968.

44. Pandeya SC, Puri GS, Singh JS. Research methods in plant ecology. Asia Publishing House, New York; 1968.

45. Piper CS. Soil and plant analysis. Interscience Publishers, Inc., New York; 1944.

46. Bremner JM. Nitrogen-total. In: Sparks DL, Page AL, Helmke PA, Loepert RH, Soltanpour PN, Tabatabai MA, Johnston CT, Sumner ME (eds.). Methods of soil analysis, part 3, chemical methods, soil science society of America and American society of agronomy, Madison, Wisconsin, USA. 1996;1085–1121.

47. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture Circular (No. 939), Washington, D.C; 1954.

48. Morwin HD, Peach PM. Exchangeability of soil potassium in the sand, silt, and clay fractions as influenced by the nature of the complementary exchangeable cation. Soil Science Society of America Journal. 1951;15(C):125–128. Available:https://doi.org/10.2136/sssaj1951.036159950015000c0026x

49. Nelso, DW, Sommers LE. Total carbon, organic carbon, and organic matter. In: Sparks DL, Page AL, Helmke PA, Loepert RH, Soltanpour PN, Tabatabai MA, Johnston CT, Sumner ME (eds.). Methods of Soil Analysis, Part 3. Chemical Methods. Soil Science Society of America and American Society of Agronomy, Madison, Wisconsin, USA. 1996;961–1010.

50. Chawla A, Yadav PK, Uniyal SK, Kumar A, Vats SK, Kumar S, Ahuja PS. Long-term ecological and biodiversity monitoring in the western Himalaya using satellite remote sensing. Current Science. 2012;102(8):1143–1156.

51. Prakash P. Grazing management in temperate grassland of Kumaun Himalaya for soil water conservation. Journal of Applied and Natural Science. 2013;5(2):345–349. Available:https://doi.org/10.31018/jans.v5i2.330

52. Tete-Mensah I. Evaluation of some physical and chemical properties of soils under two agroforestry practices. M.Phil Thesis, University of Ghana; 1993.

53. Izwaida CA, Mohd EW, Mugunthan P, Ho SY. Soil under enrichment planting: assessing soil properties at reforestation sites of Sabal Forest Reserve; 2015. Conference paper, Available on Available:https://www.researchgate.net/publication/321996444

54. Chen ZS, Hsieh CF, Jiang FY, Hsieh TH, Sun IF. Relations of soil properties to topography and vegetation in a subtropical rain forest in southern Taiwan. Plant Ecology. 1997;132:229–241. Available:https://doi.org/10.1023/a:1009762704553

55. Charan G, Bharti VK, Jadhav SE, Kumar S, Acharya S, Kumar P, Gogoi D, Srivastava RB. Altitudinal variations in soil physicochemical properties at cold desert high altitude. Journal of Soil Science and Plant Nutrition. 2013;13(2):267–277. Available:http://dx.doi.org/10.4067/s0718-95162013030500023

56. Wang C, Zhao C, Xu Z, Wang Y, Peng H. Effect of vegetation on soil water retention and storage in a semiarid alpine forest catchment. Journal of Arid Land. 2013;5(2):207–219. Available:https://doi.org/10.1007/s40333-013-0151-5

57. Joshi PC, Pandey P, Kaushal BR. Analysis of some physicochemical parameters of soil from a protected forest in Uttarakhand. Nature and Science. 2013;11(1):136–140.
58. Toth B, Weynants M, Nemes A, Mako A, Bilas G, Toth G. New generation of hydraulic pedotransfer functions for Europe. European Journal of Soil Science. 2015;66(1):226–238. Available:https://doi.org/10.1111/ejss.12192

59. Kumar M, Kumar S, Sheikh MA. Effect of altitudes on soil and vegetation characteristics of Pinus roxburghii forest in Garhwal Himalaya. Journal of Advanced Laboratory Research in Biology. 2010;1(2):130–133.

60. Deb P, Deb Nath P, Pattanaaik SK. Physicochemical properties and water holding capacity of cultivated soils along altitudinal gradient in South Sikkim, India. Indian Journal of Agricultural Research. 2014;48(2):120–126. Available:https://doi.org/10.5958/j.0976-058x.48.2.020

61. Perry DA. Forest ecosystems, The Johns Hopkins University Press. Baltimore, Maryland, USA; 1994.

62. Suleiman R, Jimoh IA, Aliyu J. Assessment of soil physical and chemical properties under vegetable cultivation in Abia Metropolitan Area, Nigeria. Zaria Geographer. 2017;24(1):89–99.

63. Mehta JP, Pharswan K, Subodh. Effect of prescribed fire on some driving & abiotic variables of protected and grazing sites at Pauri, Garhwal Himalaya. New York Science Journal. 2011;14(2):1–7.

64. Kumar M, Rajwar GS, Sharma CM. Disturbance and the dynamics in a sub-tropical forest of Garhwal Himalaya. Bulletin of the Institute of Ecology. 2004;14:43–50.

65. Kala CP, Rawat GS, Uniyal VK. Ecology and Conservation of the valley of flower national park, Garhwal Himalaya. Final Technical Report, Wildlife Institute of India, Dehradun; 1998.

66. Nazir T. Estimation of site quality of important temperate forest cover on the basis of soil nutrient and growing stock in Garhwal Himalaya. D.Phil. Thesis, HNB Garhwal University, Srinagar (Garhwal), Uttarakhand, India; 2009.

67. Bhattacharyya T, Pal DK, Mandal C, Chandran P, Ray SK, Sarkar D, Veimourougane K, Srivastava A, Sidhu GS, Singh RS, Sahoo AK, Dutta D, Nair KM, Srivastava R, Tiwary P, Nagar AP, Nimkhedkar SS. Soils of India: historical perspective, classification and recent advances. Current Science. 2013;104(10):1308–1323.

68. Weil RR, Magdoff F. Significance of soil organic matter soil quality and health. In: Magdoff F, Weil RR (eds.), Soil Organic Matter in Sustainable Agriculture. CRC Press, Boca Raton, Florida. 2004;1–43.

69. Aliero MM, Ismail MH, Alias MA, Mohd SA, Abdullahi S, Kalgo SH, Kwaido AA. Assessing soil physical properties variability and their impact on vegetation using geospatial tools in Kebbi State, Nigeria. In: IOP Conference Series: Earth and Environmental Science. 2018;169(1):012111. IOP Publishing Ltd. Available:https://doi.org/10.1088/1755-1315/169/1/012111

70. Khera N, Kumar A, Ram J, Tewari A. Plant biodiversity assessment in relation to disturbances in mid-elevational forest of Central Himalaya, India. Tropical Ecology. 2001;42(1):83–95.

71. Gairola S, Sharma CM, Ghildiyal SK, Suyal S. Chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya, India. Environmentalist. 2012;32(4):512–523. Available:https://doi.org/10.1007/s10669-012-9420-7

72. Hoque AE, Nazrul-Islam AKM, Imamul-Huq SM. Seasonal variation of edaphic features of Madhupur Sal Forest, Bangladesh. Ecoprint. 2008;15:7–14.

73. Bahuguna YM, Gairola S, Semwal DP, Uniyal PL, Bhatt AB. Soil physicochemical characteristics of bryophytic vegetation residing Kedarnath Wildlife Sanctuary (KWLS), Garhwal Himalaya, Uttarakhand, India. Indian Journal of Science and Technology. 2012;5(4):2547–2553.

74. Aliyu J, Aliyu N, Jimoh IA, Alasinrin SK, Agaku TD. Pedological characteristic, classification and fertility implication of floodplain soil at Dakate, Zaria, Kaduna State. Nigerian Journal of Soil and Environmental Research. 2016;14(1):216–228.

75. Rathore JS. Studies in the forest soils of Sagar. Tropical Ecology. 1971;12(1):101–111.

76. Thadani R, Ashton PMS. Regeneration of banj oak (Quercus leucotrichophora A. Camus) in the central Himalaya. Forest Ecology and Management. 1995;78(1-3):217–224. Available:https://doi.org/10.1016/0378-1127(95)03561-4
77. Paul EA, Clark FE. Soil Microbiology and Biochemistry. Academic Press, San Diego; 1996.

78. Nelofer J, Naheed S, Humaira A, Zubia M, Zahoor AB, Khan R, Anjum N, Akmal F, Arbab N, Tareen P, Khan R. Physical and chemical properties of soil quality indicating forests productivity: A review. American-Eurasian Journal of Toxicological Sciences B. 2016;60–68. Available: https://doi.org/10.5829/idosi.aejts.2016.8.2.10312

79. Amonum JI, Dawaki SA, Dachung G. Effects of plant species on the physicochemical properties of soil in Falgore Game Reserve, Kano State. Nigeria. Asian Journal of Environment & Ecology. 2019;9(4):1–11. Available: https://doi.org/10.9734/ajee/2019/v9i430100

80. Kumar M, Sharma CM, Rajwar GS. Physicochemical properties of forest soil along altitudinal gradient in Garhwal Himalaya. Journal of Hill Research. 2004;17(2):60–64.

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