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

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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

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the physical properties of soils either do not vary across the three depths (0–10 cm, 11–20 cm, and 21–30 cm) or show slight changes whereas chemical properties show notable variations comparatively. The significant variation (ANOVA, $P < 0.05$) was observed in the soil texture (sand, silt, and clay contents), moisture content, water holding capacity, and nitrogen content across the six forest types (study sites). The soil texture ranged between loam and sandy loam which is considered supportive for plant growth. Besides, the lower bulk density and higher soil organic carbon and organic matter with other determined parameters in the studied soils indicate that the studied six forests have sustained nutritive soils. It can be concluded from the present results that the soil physicochemical properties vary with changes in the vegetation composition (forest types) at different elevations in Western Himalaya. Further elaborative study will be done to ascertain interrelationship among the vegetation and soils.

Keywords: Himalayan forests; elevation; composite soil sample; soil characteristics; plant nutrients.

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 29º57'33"N to 30º06'05"N latitudes and 79º11'33"E to 79º20'33"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 m^2 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 ($F_{5, 12}$ =891.27, p=0.00), silt ($F_{5, 12}$ =296.79, p=0.00) and clay ($F_{5, 12}$ =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) ($F_{5, 12}$ =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 to1.33±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 Ballabha [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% ($F_{5, 12}$ =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 these 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

70.86±2.50% (L2) ($F_{5, 12}$ =24.70, p=0.00). It varied from 56.39±4.54 to 73.65±3.76% for the upper layer, 53.32±4.37 to 70.12±3.69% for the middle and 49.45±3.67 to 68.81±2.54% for the lower layer (Table 3). This result agrees with the reports of Joshi *et al*. [57] from protected forest in Uttarakhand and Arya [35] from the protected forest in the Kumaun Himalayas. Clay percentage also play important role in the WHC of soil [61].

3.2 Soil Chemical Properties

Soil pH

The average pH of the soil was at its maximum in L2 (5.5±0.36) while at its minimum in U1 (4.83±0.21). The average value of soil pH for six sites is calculated as 5.09±0.25 ($F_{5, 12}$ =2.18, p=0.12). Among the three different soil layers, the pH ranges from 4.8±0.07 to 5.3±0.10 for upper, 4.6±0.10 to 5.4±0.05 for middle, and 4.7±0.06 to 5.9±0.03 for the lower layer of soil. The highest pH value (5.9±0.03) is recorded for the lower layer of site L2 while the lowest for the middle layer (4.6±0.10) of site U1 (Table 4). The pH values of soil lower than 7 indicate that the soils of different forests are moderately acidic in nature. These pH ranges of soils provide good growing conditions and stimulate the uptake of nutrients by plants [62]. The acidic nature of soils are also reported by Bhandari *et al*. [29], Arya [35], Chawla *et al*. [50], Joshi *et al*. [57], Mehta *et al*. [63], Kumar *et al*. [64], and Kala *et al*. [65] from different areas of Western Himalaya.

Soil organic carbon

The soil organic carbon estimation is basically for the purpose of soil fertility or health assessment. The average soil organic carbon (SOC) of different study sites vary between 0.54% (at M2) and 0.71 % (at L2), while the calculated overall mean value is 0.61±0.07% ($F_{5, 12}$ =0.47, p=0.81). The SOC is in the range of 0.435±0.11 to 0.9±0.09 at upper, 0.256±0.12 to 0.825±0.014 at middle, and 0.435±0.10 to 0.75±0.011 at the lower layer. The SOC is lowest at the middle layer of U2 (0.255±0.12), while highest at the upper layer of U2 (0.9±0.09) (Table 4). Mostly, the maximum accumulation of organic carbon is observed among the upper and middle layers of soils. The greater accumulation of organic carbon near the surfaces is probably due to the assimilation of leaf litter and the addition of decayed roots to the upper layers. Similar reports of organic carbon accumulation are also provided by Mahajan *et al*. [3], Nazir [66] and Bhattacharyya *et al*. [67].

Soil organic matter

Soil organic matter (SOM) is an important soil component affecting directly or indirectly the soil properties [68]. It serves many purposes including nutrient storage and supply, erosion prevention and increases the water holding capacity of the soils ultimately affecting the development and growth of plants [69]. The SOM of the study area ranges between 0.92±0.15 and 1.23±0.21 and the average value is 1.04±0.12 ($F_{5, 12}$ =0.44, p=0.81). SOM value for upper, middle and lower soil layers ranges from 0.75±0.12 to 1.55±0.16, 0.44±0.55 to 1.42±0.23 and 0.74±0.35 to 1.29±0.93 respectively (Table 4). The resulted values are comparable to the reports of Nazir [66], Khera *et al*. [70], Gairola *et al*. [71] and Hoque *et al*. [72]. The considerable amount of organic matter content noted in the soils of the different forest types perhaps attributed to the decomposition of plant remains from dead soil macro-fauna and micro-organisms in the reserves.

Nitrogen, available phosphorus and exchangeable potassium

The maximum nitrogen content (0.093%) has been recorded for site L2, followed by L1 (0.081%), while minimum nitrogen (0.041%) has been observed for site M2 ($F_{5, 12}$=43.49, p=0.00). It ranges 0.038–0.095% for top layers, 0.04–0.093% for middle layers and 0.044–0.092% for lower layers of different study sites (Table 5). The present report is in agreement with Mahajan *et al*. [3], Chawla *et al*. [50], Nazir [66], Khera *et al*. [70], and Gairola *et al*. [71]. The mean 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} ($F_{5,\ 12}$ =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 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 ($F_{5,\ 12}$ =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=-0.636, p=0.175), 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), *Lyonia ovalifolia* (Angyar, Ayar)
M2	Deopuri-Angyari	1800–2300	570	*Rhododendron arboreum* (Burans), *Quercus floribunda* (Tiyuj), *Quercus oblongata* (Banj)
U1	Kodiyabagarh-Kothki	2500–3000	830	*Abies pindrow* (Rainsaw), *Quercus semecarpifolia* (Khair), *Quercus floribunda* (Tiyuj)
U2	Bakharkhet-Chorani	2100–2700	540	*Abies pindrow* (Rainsaw), *Quercus semecarpifolia* (Khair), *Quercus floribunda* (Tiyuj)

*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±3.28
	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	0.68±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±4.37
	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	0.75±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	0.900±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	32.560±2.08	259.84±15.78	5.58
	11-20	0.081	29.600±3.99	219.52±21.90	9.63
	21-30	0.084	24.568±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	29.008±0.09	207.20±30.80	6.16
	11-20	0.093	28.416±1.33	264.32±33.89	8.87
	21-30	0.092	25.456±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	24.800±3.31	208.32±28.50	12.46
	11-20	0.062	34.400±4.19	196.00±31.80	9.19
	21-30	0.070	38.480±3.67	257.60±324.69	7.50
	Mean±S.D.	0.064±0.007	32.56±7.02	220.64±32.60	9.72
M2	0-10	0.038	31.080±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	34.152±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	20.654±2.80	268.80±33.55	10.00
	11-20	0.048	24.208±3.67	197.12±37.39	14.06
	21-30	0.048	31.968±4.13	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	32.856±0.09	183.68±10.08	20.93
	11-20	0.045	31.672±1.88	174.72±10.69	5.67
	21-30	0.046	34.336±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

Table 6. Correlation between various physicochemical properties of soil

	pH	WHC	Moisture	BD	N	P	K	OC	SOM
WHC	0.232 (0.658)#	1.00							
Moisture	-0.636 (0.175)	-0.595 (0.213)	1.00						
BD	-0.323 (0.533)	0.078 (0.884)	-0.254 (0.627)	1.00					
N	0.375 (0.464)	0.375 (0.463)	-0.917* (0.010)	0.423 (0.404)	1.00				
P	0.218 (0.678)	-0.718 (0.108)	0.314 (0.544)	-0.105 (0.843)	-0.325 (0.530)	1.00			
K	0.003 (0.996)	0.292 (0.574)	-0.603 (0.205)	0.317 (0.541)	0.792 (0.060)	0.673 (0.143)	1.00		
OC	0.526 (0.283)	0.513 (0.298)	-0.978** (0.001)	0.341 (0.509)	0.958** (0.003)	-0.257 (0.623)	0.619 (0.190)	1.00	
SOM	0.413 (0.394)	0.437 (0.386)	-0.943** (0.005)	0.340 (0.510)	0.994** (0.000)	-0.351 (0.496)	0.776 (0.070)	0.972** (0.001)	1.00
C:N	-0.225 (0.668)	-0.315 (0.543)	0.846* (0.034)	-0.500 (0.313)	-0.983** (0.000)	0.305 (0.557)	-0.785 (0.064)	-0.922** (0.009)	-0.966** (0.002)

***Correlation is significant at 0.01 level, * Correlation is significant at 0.05 level, #P value is given in parenthesis. Abbreviations: WHC=water holding capacity, BD=bulk density, N=nitrogen, P=phosphorus, K=potassium, OC=organic carbon, SOM=soil organic matter*

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.

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