

## Physico-chemical characterization of Oak, Pine and Sal forest soil profiles of Betalghat Region of Kumaun Himalaya

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### Abstract

Soil is one of the basic natural resources on which all forms of terrestrial life co-exist. The soils of three forest types i.e., banj-oak (*Quercus leucotrichophora* A. Camus) chir-pine (*Pinus roxburghii* Sargent) and sal (*Shorea robusta* Gaertn. f.) of Betalghat block, Nainital District, (Kumaun Himalaya). Soils were drawn from three depths viz. 0-10 cm, 11-20 cm, 21-30 cm. The present study were studied resulted to soil physico-chemical properties i.e. maximum soil texture (sand 34.30 %, silt 57.21 % and clay 33.23 %), soil moisture (12.6 %), bulk density (1.43 g.cm<sup>-3</sup>), porosity (52.06%), water holding capacity (69.27%) and the maximum values of chemical analysis i.e. pH (6.80), total carbon (3.82 %), organic matter (6.57 %), total nitrogen (0.36 %), available potassium (267 mg/kg) and available phosphorous (62 mg/kg). Banj-oak forest shows rich physical properties followed by sal and chir-pine forest while chir-pine forest shows rich chemical properties in compared to sal and banj-oak forest.

**Keywords:** Soil physico-chemical characterization, Betalghat region, banj-oak, chir-pine, sal forest, Kumaun Himalaya.

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### Introduction

Physico-chemical characteristics of forest soils vary in space and time because variation in climate, topography, weathering processes, vegetation cover and several other biotic and abiotic factors (Paudel and Sah, 2003; Sheikh and Kumar, 2010). Forest soil influenced the composition of forest stand and ground cover, rate of tree growth (Bhatnagar, 1965). The vegetation influences the physico-chemical properties of the soil to a great extent. It improves the soil structure, infiltration rate and Water Holding Capacity and aeration (Ilorkar and Totey, 2001; Kumar et al., 2004; Champan and Reiss, 1992). The nutrient thus, returned in the soil, exerts a strong feedback on the ecosystem processes (Pastor et al., 1984). Plants are the main source of soil organic matter, which influences the physico-chemical characteristics of soil such as, texture, pH, water holding capacity and nutrients availability (Johnston, 1986). The nature of soil profile, pH and nutrient cycling between the soils and plants are the important dimensions to determine the forest site quality. The forests of central Himalayan region have vast variations in the topography, climate and soil conditions, which form a complex ecosystem. Since, the vegetation zones in this region clearly reflect climatic and edaphic variations (Bhatt and Purohit, 2009; Bhatt, 1981) and at the same time the knowledge of physical and chemical properties of soils and climatic conditions of different forest types of temperate region of central Himalaya is meagre.

In the Western Himalayan region (Uttarakhand, India), Oak (*Quercus leucotrichophora* A. Camus) and Pine (*Pinus roxburghii* Sargent) are the two major forest types spread over a large part of the forested landscape. Oak is a deep-rooted and moderate-sized evergreen tree that occurs in the moist and cool aspects in the

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lower Western Himalayan temperate forest between altitudes 1000 to 2300 m asl (Singh and Singh, 1987; Joshi and Negi, 2015). Pine is a shallow-rooted and large evergreen conifer and a principal species of the Himalayan subtropical forests, which occurs between 800 to 1700 m asl (Champion and Seth, 1968).

Sal (*Shorea robusta* Gaertn. f.) belonging to the family Dipterocarpaceae is one of the most important timber trees in India (Deka et al., 2012; Sapkota et al., 2009). Sal forest is widely distributed in tropical India and covers approx. 13.30 per cent of the total forest area of the country (Satya and Nayaka 2005). As per Champion and Seth (1968) it is one of the dominant tree species in the tropical moist as well as dry deciduous forests in India. Some previous studies about physico-chemical characterization of soil were also done by researchers in various forests of Kumaun and Garhwal Himalaya (Joshi and Negi, 2015; Khera et al., 2001; Singh et al., 2009; Semwal et al., 2009; Sharma et al., 2010; Jina et al., 2011; Gairola et al., 2012; Kumar et al., 2013; Joshi, et al., 2013; Mehta et al., 2014; Upreti et al., 2016; Tewari et al., 2016; Bharti, et al., 2016). Present study is focused on the comparison of soil physico-chemical profiling of three different forest types (Oak, Pine and Sal) of Betalghat region of Kumaun Himalaya, Uttarakhand.

## Material and Methods

### Study area

The Present study was carried during the year 2017 in Betalghat region of Nainital district lies between 29°38'925" N and 79°49'465" E, covering an area of 256.33 Km<sup>2</sup> with an altitudinal range from 700 to 1800 m asl. The region is bounded by Tarikhet and Bhikyasain block of Almora district on the north, Kotabag block of Nainital district on the south, Sult block of Almora district on west and Ramgarh block of Nainital district on the east. The vegetation of the region mainly comprises of tropical, sub-tropical and temperate forest.

### Collection of soil samples

Soil samples were collected from three dominated forest types i.e. banj-oak, chir-pine and sal forest of Betalghat region, Nainital District of Kuamun Himalaya. Samples were collected from three different depths with core viz., (i) upper (0–10 cm), (ii) middle (11–20 cm) and (iii) Lower (21–30 cm) for assessing the physico-chemical profiling of the soil. Soil sample was packed in a separate labelled plastic zipper bags and transported to the laboratory for further analysis. The soil samples were oven dried at 45 °C for 24 h to reduce the moisture. The detailed description of studied sites was given in Table1. Analytical procedure for soil physico-chemical characterization was done by various methods viz., soil texture (sieve method) (Piper, 1966), soil moisture (Jackson, 1958), water holding capacity (Piper, 1950), soil bulk density (gcm<sup>-3</sup>) (Black, 1965), soil porosity (Gupta and Dhakshinamoorthy, 1980), pH (Jackson, 1958), soil organic carbon by wet digestion method (Walkley and Black, 1934), total nitrogen by Kjeldahl digestion method (Kjeldahl, 1883), available phosphorus by 0.5 M NaHCO<sub>3</sub> (pH 8.5) extraction method (Olsen and Sommers, 1982), available potassium by 1 N NH<sub>4</sub>OAc (pH 7.0) extraction method (Black, 1965). Soil chemical properties were performed by soil testing laboratory (Uttarakhand Tea Development Board, Almora) situated at Bhowali, Uttarakhand.

Table 1. Detail description about study sites

Site	Forest Types	Altitude (m asl)	Latitude	Longitude
KP	Banj-oak	1800	29° 29' 366" N	79° 24' 240" E
HG	Chir-pine	1400	29° 28' 151" N	79° 27' 444" E
SM	Sal	700	29° 32' 870" N	79° 15' 912" E

### Statistical analysis

The data were analyzed by Analysis of Variance (ANOVA) and the means were compared by Duncan tests at a level of significance of  $p < 0.05$  using SPSS 22.0 statistical software, to see the level of correlation between different soil parameter, Pearson's correlation matrix was performed while for Cluster analysis, Ward's method was applied.

## Results and Discussion

### Soil physical characterization

Soil is an essential component of our ecosystem, as it serves as an anchorage and source of nutrients for plants. Thus it is the seat, the medium and fundamental raw material for plant growth and maintenance of forest ecosystem by different ecological processes. Among the three forest types percentage of sand ranged from 20.17 to 34.30 whereas silt ranged from 40.37 to 57.21 and percentage of clay ranged from 22.25 to 33.23. Soil moisture content ranged from 4.60 to 12.6. Bulk density ranged from 1.25 to 1.43. The percentile

of porosity ranged from 45.15 to 52.06 and maximum percentage of water holding capacity ranged from 33.90 to 69.27 (Table 2).

### Soil chemical characterization

Among the three forest type pH ranged from 5.57 to 6.80. Total organic carbon ranged from 1.72 to 3.82. Organic matter ranged from 2.96 to 6.57. Total nitrogen content ranged from 0.15 to 0.36. Potassium ranged from 93 to 267 whereas phosphorus ranged from 25 to 62 (Table 3). Nitrogen, phosphorous and potassium are referred to as the primary macronutrients of soil and most important to provide the vitality and performance of plant grown. A comparative analysis of soil physico-chemical properties of oak, pine and sal forest in different parts of the region studied by various workers is given in Table 4.

### Correlation among soil physico-chemical properties

In Banj-oak forest on the basis of correlation matrix sand, carbon and phosphorous showed maximum positive correlation with four physico-chemical properties. Sand with potassium, carbon, organic matter and phosphorus. Carbon with phosphorus, sand, potassium and organic material. Phosphorus with sand, potassium, carbon and organic material while water holding capacity show maximum negative correlation with sand, potassium, carbon, organic material and phosphorus while in Chir-pine forest carbon showed maximum positive correlation five physico-chemical properties viz. sand, clay, potassium, organic matter, nitrogen while water holding capacity showed maximum negative correlation with four physico-chemical properties viz. sand, potassium, carbon and organic material and in Sal forest silt, c:n ratio, potassium, carbon and nitrogen showed maximum correlation with all physico-chemical properties. Silt with c:n ratio, potassium, carbon, organic matter and nitrogen. c:n ratio with silt, potassium, carbon, organic material, and nitrogen. Potassium with silt, c:n ratio, carbon, organic material and nitrogen. Carbon with organic material, nitrogen, silt, c:n ratio and potassium. Nitrogen with silt, c:n ratio, potassium, carbon, and organic material while clay showing maximum negative correlation with silt, c:n ratio, potassium, carbon, organic material and nitrogen (Table 5, 6, 7).

### Cluster analysis for physical properties

Cluster analysis of sand showed three clusters, cluster I (four sites), cluster II (three sites) and cluster III (two sites). While silt showed four clusters, cluster I (three sites), cluster II (three sites), cluster III (two sites) and cluster IV (one site), clay showed four clusters, cluster I (four sites), cluster II (two sites), cluster III (one site) and cluster IV (two site), moisture content showed four clusters, cluster I (three sites), cluster II (three sites), cluster III (two site) and cluster IV (one site), bulk density showed three clusters, cluster I (three sites), cluster II (three sites) and cluster III (three site), porosity showed three clusters, cluster I (three sites), cluster II (three sites) and cluster III (three site) and water holding capacity showed five clusters, cluster I (three sites), cluster II (Two sites), cluster III (One site), cluster IV (Two site) and cluster V (one site) (Figure 1).

### Cluster analysis for chemical properties

Cluster analysis of pH showed five clusters, cluster I (three sites), cluster II (Two sites), cluster III (One site), cluster IV (Two site) and cluster V (one site). While carbon showed four clusters, cluster I (three sites), cluster II (Two sites), cluster III (One site) and cluster IV (three site), organic matter showed four clusters, cluster I (three sites), cluster II (Two sites), cluster III (One site) and cluster IV (three site), nitrogen content showed four clusters, cluster I (three sites), cluster II (two sites), cluster III (three site) and cluster IV (one site), c:n ratio showed four clusters, cluster I (four sites), cluster II (one sites), cluster III (two site) and cluster IV (Two site), potassium showed four clusters, cluster I (two sites), cluster II (three sites), cluster III (two site) and cluster IV (Two site) and phosphorus showed three clusters, cluster I (five sites), cluster II (Two sites) and cluster III (two site) (Figure 2).

### Factor analysis for soil physico-chemical properties

In banj-oak forest factor analysis showed that sand, bulk density, porosity, potassium, carbon, organic matter, phosphorus and nitrogen were positively correlated in comparison to other physico-chemical properties (Figure 4a). Similarly in chir-pine forest nitrogen, porosity, sand, clay and carbon were positively correlated in comparison to other physico-chemical properties (Figure 5a). In sal forest factor analysis showed that potassium, silt, moisture content, c:n ratio, carbon, organic matter and nitrogen were positively correlated in comparison to other physico-chemical properties (Figure 6a). On the basis of observation plots upper depths (0-10 cm) of all the forest (KP1: banj-oak, HG1: chir-pine, SM1: Sal) showed close correlation with soil physico-chemical properties (Figure 4,5,6b).

Table 2. Soil physical properties of three forest types (Oak, Pine, Sal) of Betalghat

Sites	Forest Types	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Moisture Content (%)	Bulk Density (gm/cm <sup>3</sup> )	Porosity (%)	Water Holding Capacity
KP	Banj-oak	0-10	34.30±0.56 <sup>e</sup>	40.37±0.65 <sup>a</sup>	25.33±0.65 <sup>b</sup>	10.1±0.56 <sup>c</sup>	1.40±0.026 <sup>bc</sup>	46.13±0.57 <sup>abc</sup>	54.97±0.85 <sup>e</sup>
KP	Banj-oak	11-20	31.22±0.59 <sup>d</sup>	42.39±0.66 <sup>b</sup>	26.39±0.66 <sup>bc</sup>	12.1±0.51 <sup>d</sup>	1.41±0.015 <sup>bc</sup>	45.82±0.56 <sup>ab</sup>	62.57±0.68 <sup>f</sup>
KP	Banj-oak	21-30	27.12±0.57 <sup>c</sup>	41.62±0.56 <sup>ab</sup>	31.25±0.59 <sup>e</sup>	12.6±0.80 <sup>d</sup>	1.43±0.009 <sup>c</sup>	45.15±0.50 <sup>a</sup>	69.27±0.58 <sup>g</sup>
HG	Chir-pine	0-10	26.35±0.56 <sup>bc</sup>	44.63±0.56 <sup>c</sup>	29.02±0.56 <sup>d</sup>	6.38±0.37 <sup>ab</sup>	1.25±0.009 <sup>a</sup>	52.06±0.73 <sup>e</sup>	33.90±0.91 <sup>a</sup>
HG	Chir-pine	11-20	24.86±0.93 <sup>b</sup>	48.03±0.97 <sup>d</sup>	27.11±0.56 <sup>bc</sup>	6.84±0.59 <sup>b</sup>	1.26±0.012 <sup>a</sup>	51.52±0.56 <sup>e</sup>	38.57±0.69 <sup>b</sup>
HG	Chir-pine	21-30	21.04±0.56 <sup>a</sup>	52.72±0.56 <sup>e</sup>	26.24±0.56 <sup>bc</sup>	5.49±0.27 <sup>ab</sup>	1.27±0.031 <sup>a</sup>	51.14±0.57 <sup>e</sup>	49.23±0.54 <sup>d</sup>
SM	Sal	0-10	20.54±0.56 <sup>a</sup>	57.21±0.58 <sup>f</sup>	22.25±0.56 <sup>a</sup>	6.38±0.66 <sup>ab</sup>	1.34±0.025 <sup>b</sup>	48.51±0.73 <sup>d</sup>	42.90±0.91 <sup>c</sup>
SM	Sal	11-20	20.39±0.69 <sup>a</sup>	46.38±0.56 <sup>cd</sup>	33.23±0.56 <sup>f</sup>	4.60±0.80 <sup>a</sup>	1.35±0.015 <sup>b</sup>	48.03±0.56 <sup>cd</sup>	50.23±0.51 <sup>d</sup>
SM	Sal	21-30	20.17±0.57 <sup>a</sup>	51.74±0.56 <sup>e</sup>	28.09±0.51 <sup>cd</sup>	5.49±0.63 <sup>ab</sup>	1.36±0.034 <sup>bc</sup>	47.60±0.79 <sup>bcd</sup>	61.23±0.52 <sup>f</sup>

Abbreviations: Soil depths in cm: 1, 2, 3 (0-10cm, 11-20cm, 21-30cm), Sites: KP: Banj-oak forest, HG: Chir-pine forest, SM: Sal forest, BD: Bulk density, MC: Moisture content, WHC: Water Holding Capacity.

Table 3. Soil chemical properties of three forest types (Oak, Pine, Sal) of Betalghat

Sites	Forest Types	Depth (cm)	pH	Total Carbon (%)	Organic Matter (%)	Total Nitrogen (%)	C:N ratio	Available Potassium (mg/kg)	Available Phosphorus (mg/kg)
KP	Banj-oak	0-10	5.66±0.03 <sup>a</sup>	3.34±0.04 <sup>e</sup>	5.74±0.03 <sup>g</sup>	0.35±0.022 <sup>cd</sup>	9.65±0.07 <sup>c</sup>	267±0.60 <sup>i</sup>	54±0.49 <sup>e</sup>
KP	Banj-oak	11-20	5.64±0.04 <sup>a</sup>	3.16±0.03 <sup>de</sup>	5.44±0.02 <sup>f</sup>	0.33±0.015 <sup>cd</sup>	9.58±0.07 <sup>bc</sup>	241±0.73 <sup>h</sup>	48±0.71 <sup>d</sup>
KP	Banj-oak	21-30	5.57±0.04 <sup>a</sup>	2.89±0.05 <sup>cd</sup>	4.97±0.07 <sup>e</sup>	0.30±0.012 <sup>c</sup>	9.70±0.05 <sup>c</sup>	213±0.91 <sup>f</sup>	41±0.60 <sup>c</sup>
HG	Chir-pine	0-10	6.66±0.05 <sup>a</sup>	2.78±0.03 <sup>c</sup>	4.78±0.04 <sup>d</sup>	0.23±0.023 <sup>b</sup>	12.09±0.03 <sup>g</sup>	167±0.54 <sup>e</sup>	62±0.54 <sup>g</sup>
HG	Chir-pine	11-20	6.74±0.03 <sup>a</sup>	2.08±0.05 <sup>b</sup>	3.58±0.04 <sup>c</sup>	0.19±0.015 <sup>ab</sup>	10.95±0.03 <sup>e</sup>	112±0.82 <sup>b</sup>	61±0.63 <sup>fg</sup>
HG	Chir-pine	21-30	6.80±0.05 <sup>a</sup>	1.79±0.13 <sup>a</sup>	3.08±0.03 <sup>b</sup>	0.15±0.035 <sup>a</sup>	11.93±0.04 <sup>f</sup>	93±1.05 <sup>a</sup>	56±1.21 <sup>e</sup>
SM	Sal	0-10	6.31±2.55 <sup>a</sup>	3.82±0.14 <sup>f</sup>	6.57±0.03 <sup>h</sup>	0.36±0.003 <sup>d</sup>	10.61±0.03 <sup>d</sup>	220±1.31 <sup>g</sup>	33±0.49 <sup>b</sup>
SM	Sal	11-20	5.95±4.23 <sup>a</sup>	1.72±0.10 <sup>a</sup>	2.96±0.04 <sup>a</sup>	0.20±0.006 <sup>ab</sup>	8.60±0.01 <sup>a</sup>	132±1.41 <sup>c</sup>	25±0.89 <sup>a</sup>
SM	Sal	21-30	6.18±3.31 <sup>a</sup>	2.93±0.13 <sup>cd</sup>	5.04±0.03 <sup>e</sup>	0.31±0.002 <sup>cd</sup>	9.45±0.01 <sup>b</sup>	160±1.20 <sup>d</sup>	59±0.80 <sup>f</sup>

Abbreviations: K: Potassium, C: Carbon, P: Phosphorus, N: Nitrogen

Table 4. Comparative studies of soil physico-chemical properties of oak, pine and sal forests.

Forest type	Sand (%)	Silt (%)	Clay (%)	Moisture Content (%)	Bulk Density (gm/cm <sup>3</sup> )	Porosity (%)	Water Holding Capacity	References	Regions	
Oak	34.30	42.39	31.25	12.60	1.36	46.13	69.27	Present study	Kumaun	
	29.80	34.84	39.02	-	-	-	-	Semwal et al. (2009)	Garhwal	
	53.50	23.70	18.30	13.00	1.29	51.25	67.17	Sharma et al. (2010)	Garhwal	
	74.93	17.82	17.67	13.18	-	-	-	Sheikh and Kumar (2010)	Garhwal	
	43.74	52.08	4.17	6.82	1.62	38.93	43.34	Jina et al. (2011)	Kumaun	
	80.17	37.97	9.67	18.79	1.44	-	59.50	Kumar et al. (2013)	Garhwal	
	26.35	52.72	29.02	6.84	1.27	52.06	49.23	Present study	Kumaun	
	39.57	29.45	35.30	-	-	-	-	Semwal et al. (2009)	Garhwal	
	46.20	17.35	36.42	7.11	-	-	31.28	Sheikh and Kumar (2010)	Garhwal	
	45.88	49.56	4.55	7.25	1.94	94.00	43.44	Jina et al. (2011)	Kumaun	
Pine	40.87	29.52	9.67	6.29	1.45	-	47.88	Kumar et al. (2013)	Garhwal	
	20.54	57.21	33.23	6.38	1.36	48.51	61.23	Present study	Kumaun	
	60.12	28.59	12.24	7.34	-	-	43.03	Paudel et al. (2003)	Eastern Nepal	
	27.70	23.36	62.86	5.82	1.47	47.87	54.80	Bharti et al. (2016)	Kumaun	
	Forest type	pH	Total Carbon (%)	Organic Matter (%)	Total Nitrogen (%)	C:N ratio	Available Potassium (mg/kg)	Available Phosphorus (mg/kg)	References	Regions
	Oak	5.66	3.34	5.74	0.35	9.54	267 mg/kg	54 mg/kg	Present study	Kumaun
		6.90	2.83	4.87	0.24	11.80	2.86 %	0.92 %	Semwal et al. (2009)	Garhwal
		6.27	2.19	3.77	0.23	9.52	225.76 kg ha <sup>-1</sup>	22.25 kg ha <sup>-1</sup>	Sheikh and Kumar (2010)	Garhwal
		5.50	2.93	5.05	0.33	8.88	388.57 kg ha <sup>-1</sup>	56.00 kg ha <sup>-1</sup>	Jina et al. (2011)	Kumaun
		5.90	1.40	2.41	0.07	19.40	-	-	Kumar et al. (2013)	Garhwal
6.28		3.28	5.64	0.57	5.75	-	-	Joshi & Negi (2015)	Kumaun & Garhwal	
7.06		0.78	1.35	0.66	-	0.0463%	0.0105%	Tewari et al. (2016)	Uttarakhand	
5.50		2.44	4.21	0.17	14.49	40.67 mg/kg	5.75 mg/kg	Gairola et al. (2012)	Garhwal	
6.80		2.78	4.78	0.23	12.09	167.00 mg/kg	62.00 mg/kg	Present study	Kumaun	
5.50		2.86	4.92	0.23	12.43	3.66 %	0.92 %	Semwal et al. (2009)	Garhwal	
Pine	6.16	1.63	2.80	0.15	10.87	16.88 kg ha <sup>-1</sup>	164.22 kg ha <sup>-1</sup>	Sheikh and Kumar (2010)	Garhwal	
	6.50	2.76	4.75	0.19	14.53	263.67 kg ha <sup>-1</sup>	48.36 kg ha <sup>-1</sup>	Jina et al. (2011)	Kumaun	
	6.97	1.13	1.94	0.056	20.18	-	-	Kumar et al. (2013)	Garhwal	
	6.33	1.64	2.82	0.28	5.86	-	-	Joshi & Negi (2015)	Kumaun & Garhwal	
	7.07	1.51	2.59	0.352	-	0.0403%	0.0163%	Tewari et al. (2016)	Uttarakhand	
	6.31	3.82	6.57	0.36	10.61	220 mg/kg	59 mg/kg	Present study	Kumaun	
	4.33	1.41	2.42	0.12	11.75	267.73 kg ha <sup>-1</sup>	76.64 kg ha <sup>-1</sup>	Paudel et al. (2003)	Eastern Nepal	
	6.30	0.79	1.36	0.06	13.17	-	-	Sapkota et al. (2009)	Nepal	
	7.20	1.37	2.36	0.28	4.89	0.0109 %	0.0098 %	Bharti et al. (2016)	Kumaun	

Table 5. Correlation matrix among soil physico-chemical properties of Banj-oak Forest, Betalghat

	Sand	Silt	Clay	BD	MC	Porosity	WHC	CN	K	C	OM	P	N	pH
Sand	1	-0.179	-.794*	-0.277	-0.527	.678*	-.903**	-0.131	.908**	.911**	.957**	.914**	.684*	0.608
Silt		1	0.431	0.291	.804**	0.457	0.555	0.226	-0.413	-0.405	-0.335	-0.346	-0.087	0.03
Clay			1	0.439	.741*	-0.172	.916**	0.468	-.863**	-.903**	-.888**	-.822**	-0.568	-0.478
BD				1	0.451	0.091	0.421	-0.101	-0.578	-0.271	-0.337	-0.309	-0.024	-0.208
MC					1	0.179	.810**	0.058	-.678*	-0.66	-0.61	-0.614	-0.382	-0.164
Porosity						1	-0.316	0.123	0.441	0.39	0.477	0.414	0.472	0.417
WHC							1	0.254	-.946**	-.944**	-.949**	-.914**	-0.597	-0.488
CN								1	-0.206	-0.339	-0.284	-0.178	-0.086	-0.07
K									1	.904**	.929**	.844**	0.57	0.54
C										1	.979**	.902**	.692*	0.643
OM											1	.954**	.671*	0.664
P												1	0.536	0.56
N													1	.841**
pH														1

Abbreviations:BD: Bulk density, MC: Moisture content, WHC: Water Holding Capacity, CN: Carbon Nitrogen ratio, K: Potassium, C: Carbon, P: Phosphorus, N: Nitrogen

Table 6. Correlation matrix among soil physico-chemical properties of Chir-pine forest, Betalghat

	Sand	Silt	Clay	BD	MC	Porosity	WHC	C <sub>i</sub> N	K	C	OM	P	N	pH
Sand	1	-.805**	.862**	-0.299	0.626	0.611	-.850**	-0.126	.797*	.810**	.815**	.697*	0.574	-0.56
Silt		1	-0.607	0.314	-0.539	-0.148	.960**	-0.031	-.886**	-.858**	-.890**	-.673*	-0.657	.725*
Clay			1	-0.305	0.23	.783*	-.679*	0.244	.831**	.828**	.843**	0.422	0.471	-0.486
BD				1	-0.017	-0.224	0.293	-0.057	-0.347	-0.091	-0.302	-0.05	0.45	0.53
MC					1	0.243	-0.48	-0.425	0.292	0.322	0.317	0.56	0.39	-0.297
Porosity						1	-0.235	0.068	0.401	0.413	0.413	-0.029	0.118	-0.052
WHC							1	0.109	-.863**	-.844**	-.881**	-.681*	-0.659	.695*
CN								1	0.368	0.323	0.339	-0.203	0.064	-0.19
K									1	.952**	.993**	0.519	0.631	-.675*
C										1	.959**	0.544	.799**	-0.541
OM											1	0.539	0.649	-.710*
P												1	0.568	-0.566
N													1	-0.156
pH														1

Table 7. Correlation matrix among soil physico-chemical properties of Sal forest, Betalghat

	Sand	Silt	Clay	BD	MC	Porosity	WHC	CN	K	C	OM	P	N	pH
Sand	1	0.239	0.086	0.433	.745*	.834**	-0.073	0.084	-0.223	0.013	0.05	-0.148	0.022	0.204
Silt		1	-.941**	-0.051	.704*	0.328	-0.374	.981**	.800**	.955**	.979**	0.21	.960**	0.047
Clay			1	0.21	-0.469	-0.051	0.438	-.984**	-.915**	-.962**	-.979**	-0.186	-.956**	0.002
BD				1	0.386	0.381	0.277	-0.128	-0.514	-0.034	-0.103	0.234	-0.061	0.495
MC					1	.773*	-0.15	0.592	0.312	0.579	0.582	0.172	0.552	0.518
Porosity						1	-0.237	0.21	-0.061	0.167	0.157	-0.217	0.115	0.408
WHC							1	-0.471	-0.521	-0.305	-0.313	.794*	-0.209	0.037
CN								1	.869**	.966**	.984**	0.139	.956**	0.029
K									1	.819**	.844**	0.024	.798**	-0.027
C										1	.978**	0.318	.978**	0.087
OM											1	0.304	.991**	0.015
P												1	0.401	0.139
N													1	-0.02
pH														1

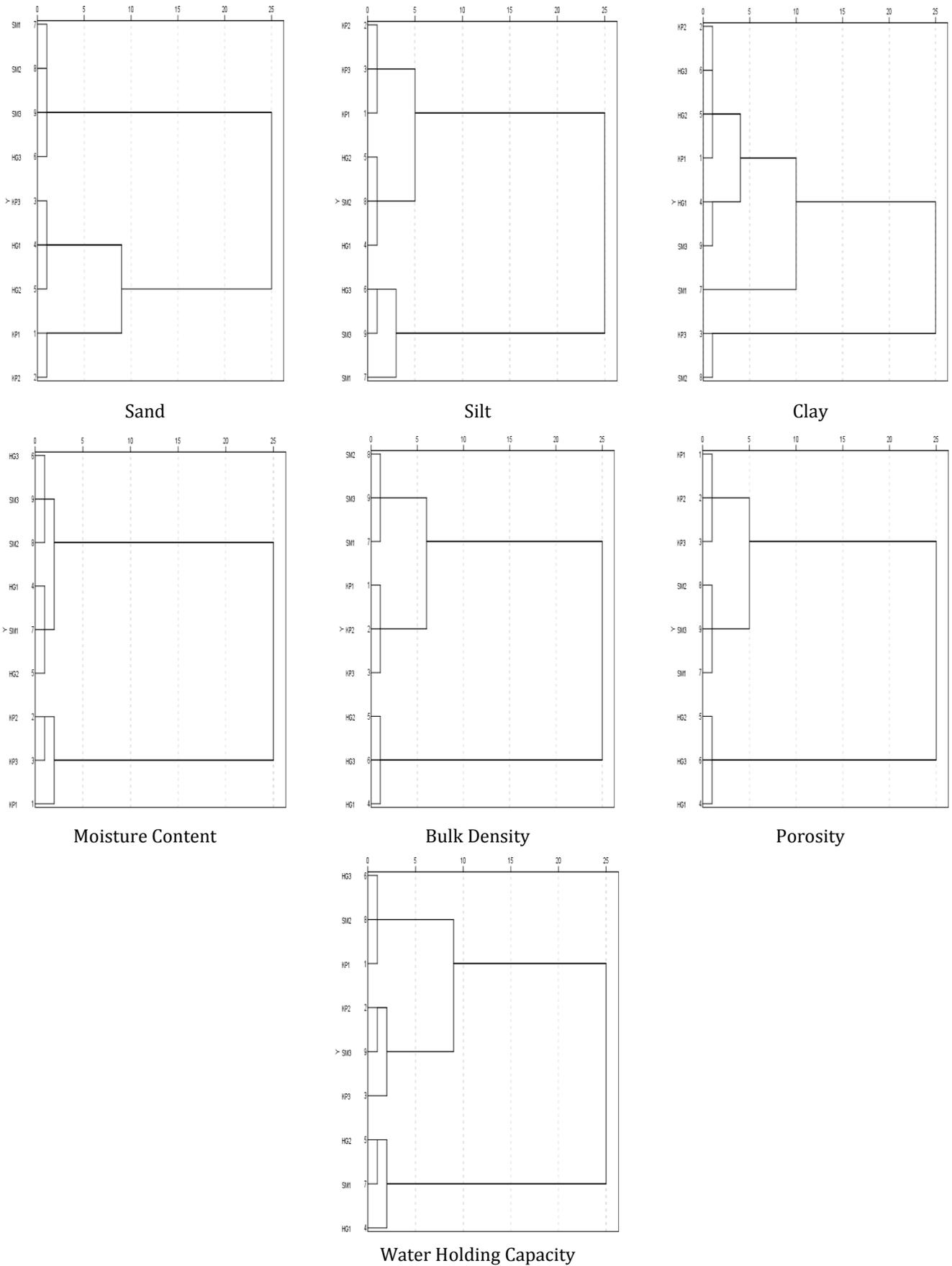


Figure 1. Dendrogram for soil physical properties of Banj-oak, Chir-pine and Sal Forest

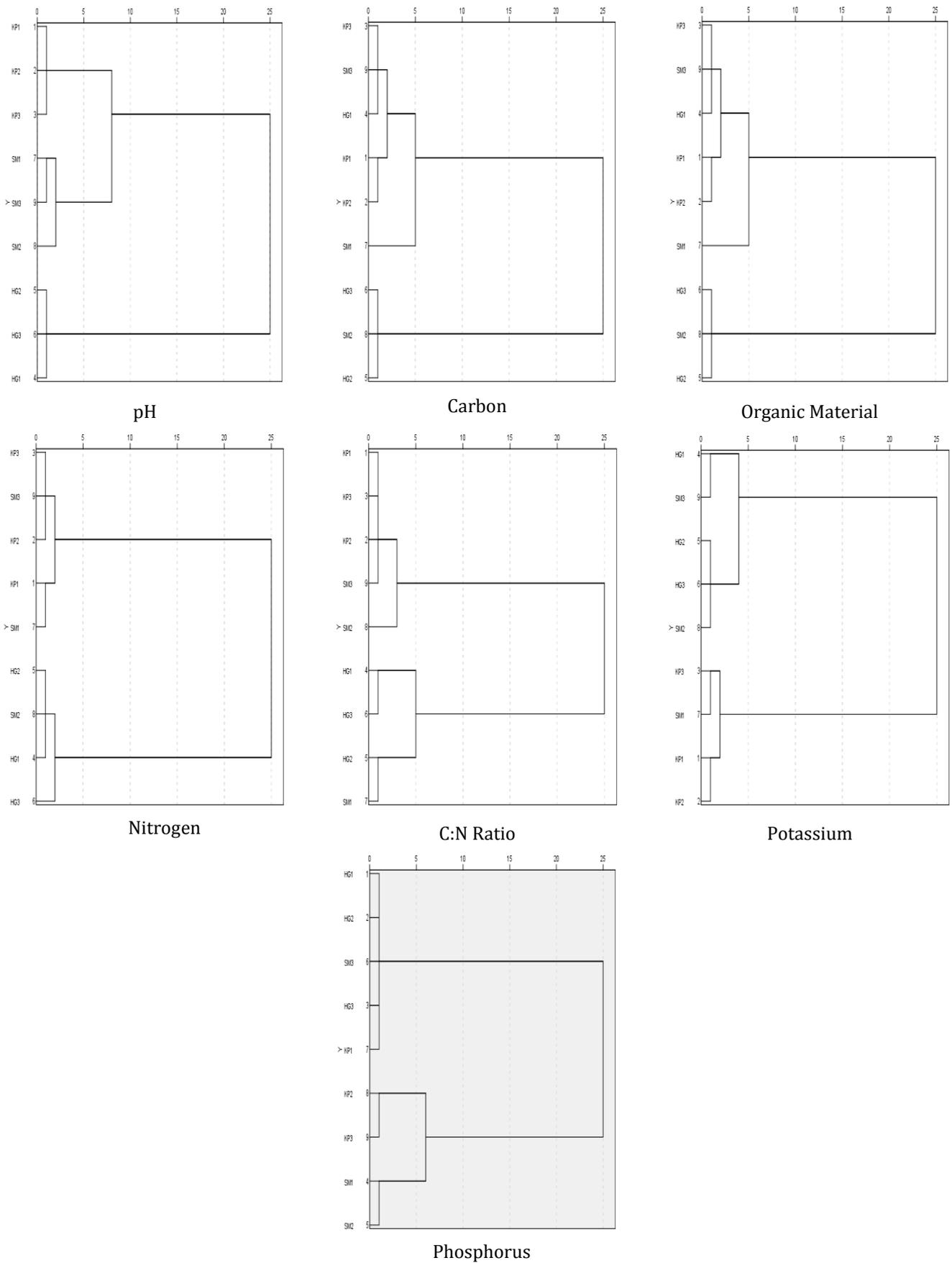


Figure 2. Dendrogram for soil chemical properties of Banj-oak, Chir-pine and Sal Forest (Abbreviations: Soil depths in cm: 1, 2, 3 (0-10cm, 11-20cm, 21-30cm), KP: Banj-oak forest, HG: Chir-pine forest, SM: Sal forest)

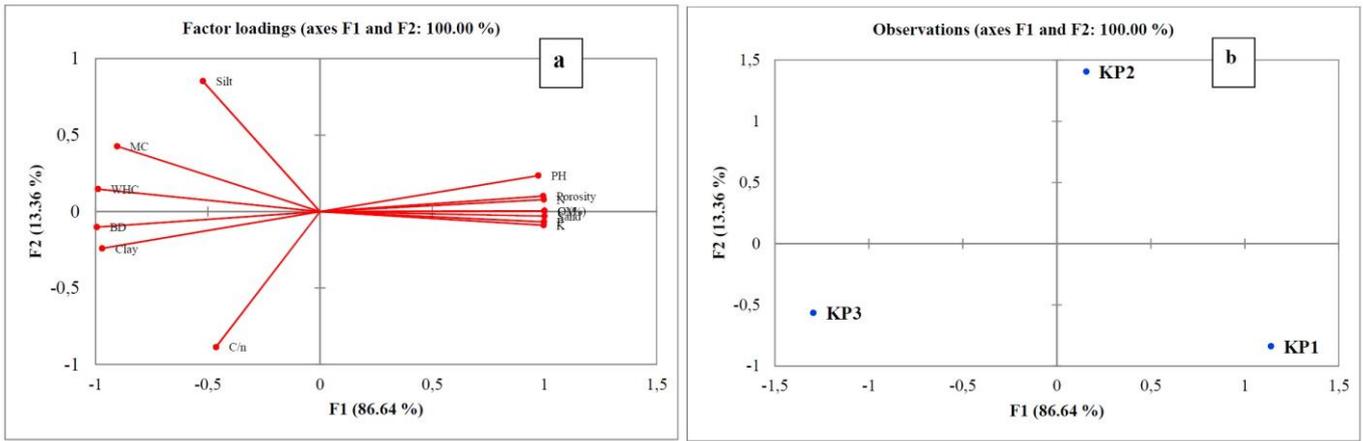


Figure 4. Factor analysis and observation plot for Physico-chemical properties of Banj-oak forest(a,b)

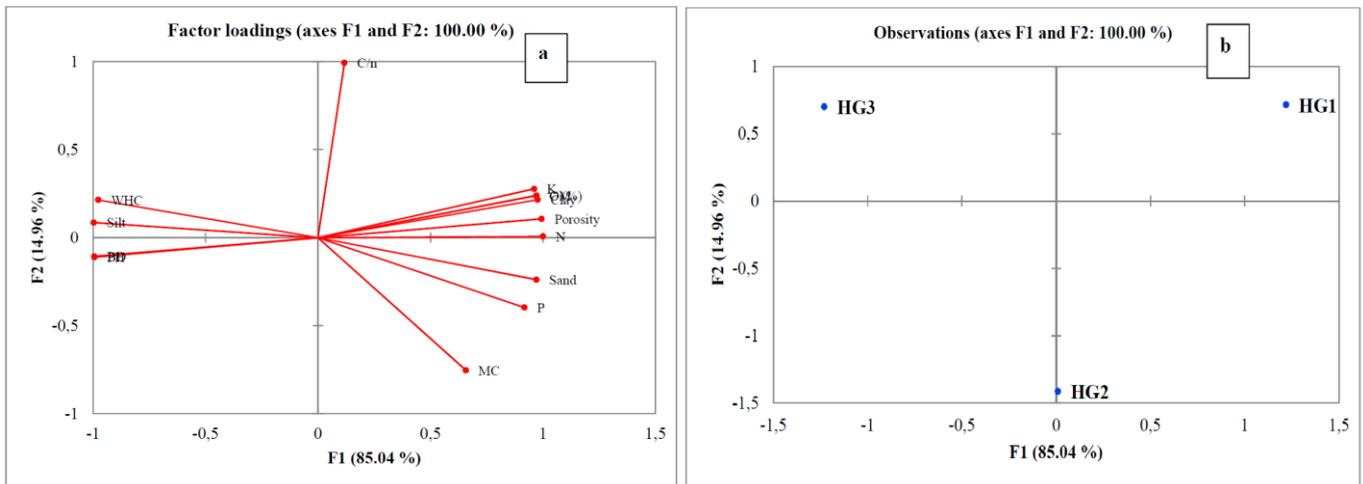


Figure 5. Factor analysis and observation plot for Physico-chemical properties of Chir-pine forest (a,b)

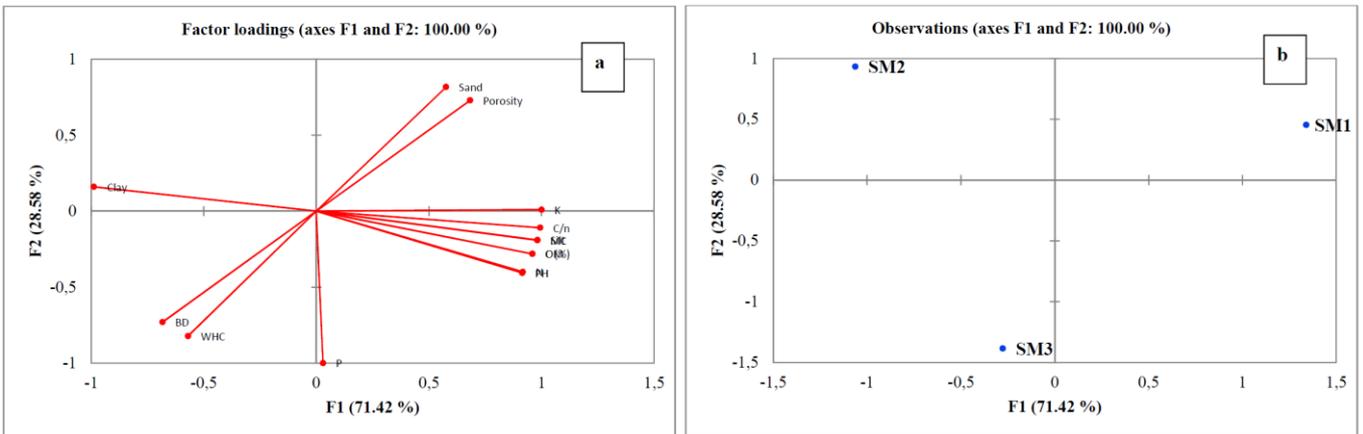


Figure 6. Factor analysis and observation plot for Physico-chemical properties of Sal forest (a,b)

## Conclusion

Observation shows that soil nutrients in banj-oak forest are rich at (21-30cm) depth while in sal and chir-pine forest soil nutrients are rich in upper most depth (0-10cm). Among all three forest type banj-oak forest shows rich values of soil physical properties (moisture content, bulk density, water holding capacity), while sal forest shows richness of chemical properties (organic carbon, organic matter, nitrogen content). Correlation analysis of soil physic-chemical properties showed that silt, c:n ratio, potassium, carbon and nitrogen have maximum positive correlation with physico-chemical properties while clay showing maximum negative correlation with physico-chemical properties. The cluster analysis concluded that soil physico-chemical properties of three depths (0-10cm, 11-20cm, 21-30cm) from three forests differentiated from each other. The factor analysis concluded that sand, porosity, carbon and nitrogen in all the forest have

maximum positive correlation in compared to other physico-chemical properties. The observation analysis concluded that upper depths (0-10 cm) of all the forest have close correlation in compared to other depths. It is a very important soil property influencing soil structure, stability, nutrient availability, soil pH and soil's reaction toward fertilizers and other amendments (Hazelton and Murphy, 2007). On the basis of above observation we concluded that mixed forest like banj-oak should promote for better soil health, which is good for germination of seeds because of high moisture content and water holding capacity.

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