Plant Archives Volume 20 No. 2, 2020 pp. 7533-7542 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

PHYSICO-CHEMICAL PROPERTIES OF SOIL IN A PROTECTED AREA NETWORK (CHUR PEAK): CHURDHAR WILDLIFE SANCTUARY IN WESTERN HIMALAYA, INDIA

Usha Thakur* and Narendra Singh Bisht

Department of Botany, D.A.V. College, Kangra-176001 (Himachal Pradesh), India.

Abstract

The present work deals the physico-chemical properties of soil along an altitudinal gradient in Churdhar Wildlife Sanctuary (CWS), Western Himalaya, India. CWS is one of the protected areas of Western Himalaya located in the state of Himachal Pradesh and covers a great range of altitude from 1900-3647 m. A total five forest sites were selected with variations in the altitudes and aspects. The composite soil samples were collected from two depth *viz.*, 0-15 cm and 15-30 cm. The soils of the area mainly falls into two textural classes *i.e.* clay-loam and sandy-loam whereas soil colour varies from yellowish brown to dark brown. Water holding capacity showed significant positive correlation with moisture content whereas nitrogen exhibited a positive correlation with organic carbon. The pH of soil decreases with increase in the altitudes.

Key words **:** Heterogeneous Environment, Resilience, Biogeochemical Cycle. Textural Triangle.

Introduction

The global centers of diversity of vascular plants are presented by high diversity of environmental abiotic factors such as diversity of climate, geology, soil and relief. Like other abiotic factors soil also influences the vegetation diversity of an ecosystem. In the soil of a region, the changes in its properties occur with time due to nutrient absorption by the floristic composition. Soil humus acts as a potent indicator of varying environmental conditions. This soil humus is formed by both biotic and abiotic factors *viz.*, altitude, bedrocks and climate (Labaz *et al.*, 2014). In a terrestrial ecosystem, soil is the major carbon sink, which plays a pivotal role in global carbon budget thus affecting the greenhouse effect. The amount of carbon present in the atmosphere together with stored in vegetation is equal to the carbon reservoir of the soil globally. The major quantity of soil organic carbon is stored by temperate forests globally as well as regionally. Soil organic carbon contains all the organic carbon having residues of both plants and animal in their various decomposition stages as well as their simple decomposition products. The plants species interactions with its abiotic factors affect the biogeochemistry of the ecosystem. Hence, alteration in floristic composition can also generate large changes in future nitrogen and carbon dynamics. Due to heterogeneous environment and topography in the mountainous regions, variations in soil organic matter or carbon are obvious. The soil and vegetation develop together thus have complex relationships with each other. The physico-chemical properties of soil are influenced by vegetation. The floristic compositions make better soil structure, aeration, water holding capacity and hydraulic conductivity. Plant tissues are the primary source that provide soil organic matter and affect the physical properties *viz.*, Water holding capacity, texture, moisture content and chemical properties such as pH and macro and micronutrients. The moisture content of the soil is also governed by its physical properties. Macronutrients being a potent constituent of soil accelerate the plant growth. They help in forming the amino acids from which majority of the biological process controlling metabolites such as proteins & enzymes are formed. The process of soil evolution has taken place over million years, but the modification in forest floor is occurring within decades, which signifies rapid environmental shifts. Clay and humus

****Author for correspondence :*** E-mail: thakurusha994@gmail.com

largely control the physical and chemical properties of the soil in the forest by acting as a centre for nutrient exchange reaction. Along these variations in biotic-abiotic components, microbial activities, climate and topography and in physical weathering result in changing physico-chemical attributes (Paudel and Sah, 2003).By taking in consideration the effects of climate, vegetation and elevation on soil's physico-chemical characteristics, it may assist in prediction of changes in future climate (Badia *et al.,* 2016). Climate directly does not have any characteristic effect on the soil's components, but by affecting the floristic composition & moisture content it shows an indirect influence on soil. Soil water controls the biological processes and chemical reactions in the soil, because this is the source through which most of the elements are transported within the ecosystem. Soil supports the terrestrial life by different processes such as ecosystem restoration & resilience and biogeochemical cycling.

Materials and Methods

Study Area

Churdhar Wildlife Sanctuary (CWS) is located in the Himachal Pradesh, Western Himalaya, India. It covers a wide altitudinal range varying from 1900-3647 m above sea level and lying between 30º48'39''- 30º54'39'' N latitude and 77º29'32''- 77º29'49 '' E longitude (Subramani *et al.,* 2014). The Sanctuary is spread over two districts (65% in Sirmour and 36% in Shimla) of the state, however present investigation is confined to the area of the sanctuary which comes under Sirmour district between 1900 and 3647 m altitudes. The climate in the sanctuary varies from cold to very cold as going from lower to higher elevation, whereas summer climate is pleasant. The rocks in the study area are igneous in origins which are primarily sedimentary and low quality metamorphosis type. The lithology of the study area comprises of many grey sandstone, where small bands of ignite and bands of clay are commonly found. Granite is largely found in the area and consists of quartz, biolite, crystals of orthoclase and tourmaline. Limestones, slates mica, gneiss, quartzites are common in (Kaur and Sharma, 2004). The soil in the study area was mainly high hilly mountainous type and showed variation in properties with the variations in altitude, climate, aspect and vegetation type. The representative species of the vegetation of the sanctuary are *Quercus leucotricophora, Rhododendron arboreum, Neolitsea pallens, Lyonia ovalifolia, Pyrus pashia, Picea smithiana, Quercus semecarpifolia, Abies pindrow* etc.

Methodology

The soil samples were collected from two depths *i.e.* upper (0-15 cm) and (ii) lower (15-30 cm) during the different seasons (summer, rainy and winter). At each sampling, the samples were collected from the 5-6 places of each site randomly and mixed (depth wise) into two composite soil samples.

Physical Properties

a) The Sieve Method given by Pandeya (1968) was used for finding the texture of soil samples. The percent of sand, silt and clay were calculated and with the help of the USDA textural triangle.

b) The Munsell soil colour chart was used for determining the colour of the soil

c) The method suggested by Mishra (1968) was followed to determining the water holding capacity of the soil.

Water Holding Capacity (WHC) =

$$\frac{W2 - W3}{W3 - W1} \times 100$$

where,

W1=Weight of empty crucible

W2= Weight of crucible with wet (saturated soil)

W3=Weight of crucible with dry soil.

d) The moisture content of the soil samples were calculated using the method suggested by Donahue *et al.,* (1987).. The moist weight of each soil sample was taken and then the sample was oven-dried at temperature 105–110º C for 24 hours and weighed again till the constant weight.

Moisture Content (%) =

$$\frac{\text{Weight of moist soil - Weight of oven dry soil}}{\text{Weight of oven dry soil}} \times 100$$

e) The bulk density determined with the help of core method in which a stainless steel core was used. The estimation of bulk density was calculated by dividing the mass *i.e.,* oven dry soil to the total volume of core.

Bulk density was calculated by using formula as:

$$\text{Bulk Density} = \frac{Ws}{Vt}$$

Ws= Weight of soil, Vt= total volume of core

Chemical Properties

a) The digital pH meter was used to measure the pH of the soil.

Table 1: Description of the study sites in the Churdhar Wildlife Sanctuary.

Site	Name of Site (Code)	Altitude range (m)	Latitude(N)	Longitude(E)	Aspect*
1.	Chogtali(CT)	1900–2200	N 30º49’52.56"	E 77º24’45.64"	NW
2.	Churas(CH)	1900–2200	N 30º48’56.19"	E 30º27’49.16"	SE
3.	Nohra 1 (NH1)	2800–3200	N30º51’9.23"	E77º26’22.31"	S
4.	Nohra 2 (NH2)	2800–3200	N30º52’29.66"	E77º26’58.15"	E
5.	PF Chur (PFC)	3600 (at summit)	N30º52’13.94"	E77º28’50.93"	SE

*SE= South East, NW= North West, S=South, E=East.

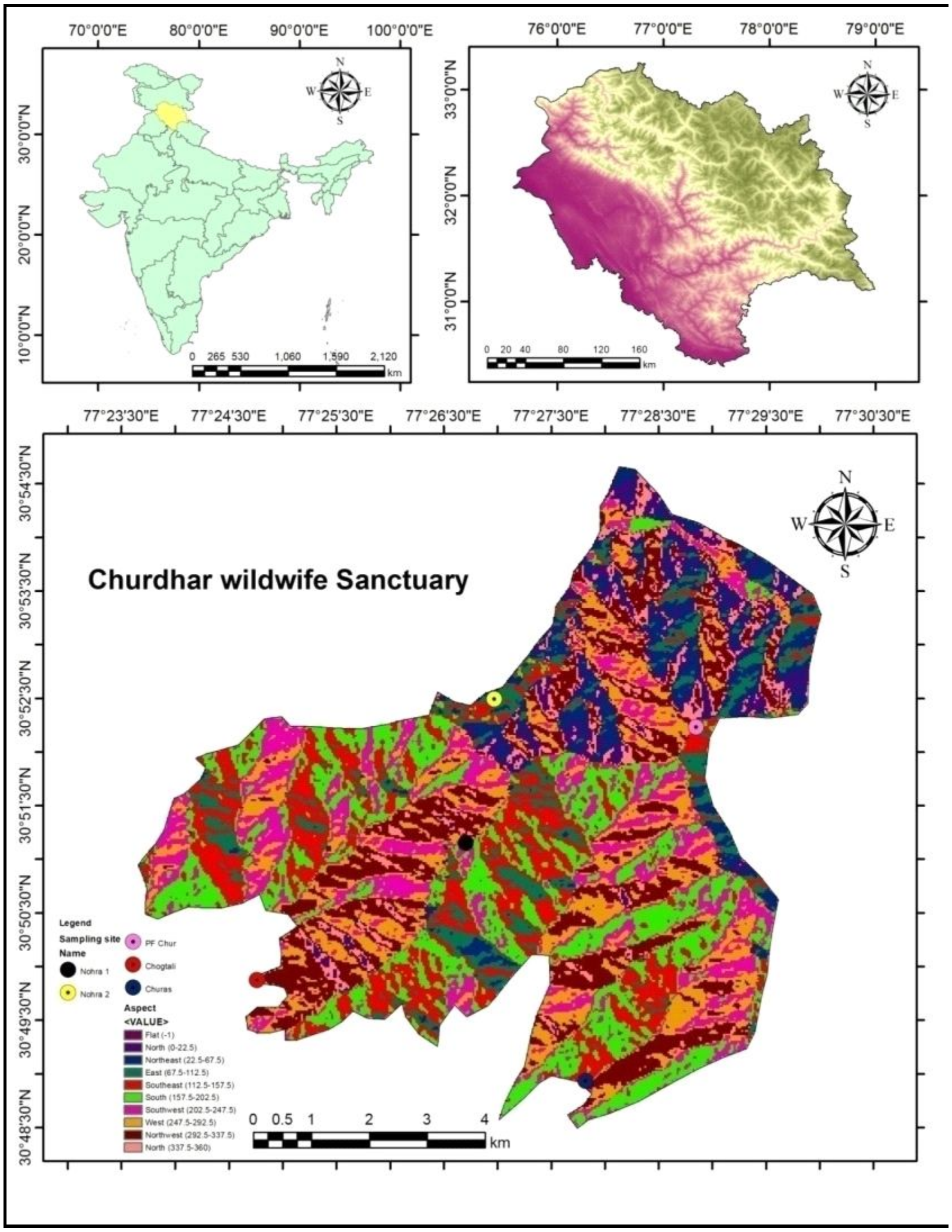

Fig. 1: Map of Study Area.

b) The organic carbon was measured by rapid titration method given by Walkley (1947) and then the soil organic matter (%) was calculated by using the factor of 1.724 of Organic carbon (%).

c) Olsen *et al.* (1954) was followed to calculate the available phosphorus.

d) Ammonium acetate method of Morwin and Peach (1951) was used to extract potassium and then estimation was done by using flame photometer.

e) Estimation of nitrogen was done following Kjeldhal procedure given by Bremner and Mulvaney (1982).

Statistical Analysis

Regression equations were calculated by using Microsoft Excel-2007 for deducing the relationship between different soil parameters and the Past Paleontological Statistics Version 3.16 was used for finding the Principal Component Analysis of soil’s parameters.

Results and Discussion

The soil textural classes of soil samples were identified on the basis of relative proportions of sand, silt and clay present in the soil sample. In the present study, only two textural classes of soil *viz.*, clay loam (CT, CH, NH1 and NH2) and sandy clay loam (PFC) were found (Table 2). The soil samples from five different study sites did not show much variation in colour. Although the soil colour varied from very pale brown to brown to very dark brown across the sites. In terms of Hue, Value and Chroma the colour of soil was defined. The Hue value varied 10YR to 7.5YR, term value 2 to 7 and Chroma 2 to 4 (Table 3). All five forests sites showed slight variation in colour along the depth. The results of other physico-chemical properties (water

Table 2: Variation in soil texture at different forest sites in the Churdhar Wildlife Sanctuary.

Site	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
CT	0-15	22	38	40	Clay Loam
	15-30	23.50	39	37.50	Clay Loam
	Average	22.75±1.06	38.5±0.70	38.75±1.76	Clay Loam
CH	0-15	24.60	37.10	38.40	Clay Loam
	15-30	23.42	36.78	39.80	Clay Loam
	Average	24.01±0.83	36.94±0.22	39.1±0.98	Clay Loam
NH1	0-15	24.10	36.70	39.20	Clay Loam
	15-30	23.50	36.50	40.00	Clay Loam
	Average	23.8±0.42	36.6±0.14	39.6±0.56	Clay Loam
NH2	0-15	25.10	35.18	39.82	Clay Loam
	15-30	24.20	36.30	39.50	Clay Loam
	Average	24.65±0.63	35.74±0.79	39.66±0.22	Clay Loam
PFC	0-15	45.59	24.42	29.99	Sandy Clay Loam
	15-30	46.23	24.77	29.00	Sandy Clay Loam
	Average	45.91±0.45	24.59±0.24	29.49±0.02	Sandy Clay Loam

Table 3: Variation in the colour of the soils at different forest sites.

Site	Depth (cm)	Hue	Value	Chroma	Colour
CT	0-15	10YR	3	3	Dark brown
	15-30	10YR	2	2	Very dark brown
CH	0-15	7.5YR	3	3	Dark brown
	15-30	7.5YR	2	2	Very dark brown
NH1	0-15	10YR	5	4	Yellow brown
	15-30	10YR	7	4	Very pale brown
NH2	0-15	7.5YR	5	2	Brown
	15-30	7.5YR	5	3	Yellow brown
PFC	0-15	10YR	5	4	Yellow brown
	15-30	10YR	6	3	Pale brown

holding capacity, moisture content, bulk density, organic carbon, soil organic matter, nitrogen content, phosphorus and potassium content) is summarized in the table 4. Considering both depths into account, the average value of WHC ranged from 85.19±1.74% (PFC) to 113.91±2.08% (CT). In the present study the WHC of five different forest sites followed the trend as PFC<CH<NH2<NH1<CT trend. The range of overall average values of soil moisture content while taking both depth in consideration were found to be from 29.86±4.21% (PFC) to57.36±7.43% (CT). PFC<CH<NH2<NH1<CT was the trend observed at the different five forests sites. The overall average of bulk density of the study area ranged from 0.7 gm/cm^3 (PFC) to 1.02gm/cm^3 (CH). Bulk density followed the trend as PFC<NH1<NH2<CT<CH.

Taking both depths into consideration, the overall pH at different study sites ranged from 5.93±0.03 (PFC) to 6.74±0.084 (CT). Thus, the nature of soil of the study area is mainly acidic. The trend of soil pH of the forests sites of the present study can be expressed as: PFC<NH2<NH1<CH<CT.

Overall average values of carbon content varied from 0.75±0.14 % (CT) to 1.61±0.30% (PFC), with the trend as: CT<CH<NH2<NH1<PFC. Overall values of soil organic matter (including different seasons and depths) ranged from 1.29±0.24% (CT) to 2.77±0.53% (PFC). CT<CH<NH2<NH1<PFC is the trend of soil organic matter of the study area.

The overall average values of phosphorus at different study sites during different seasons and depths varied from 27.82±0.43 (NH1) to 33.45±1.74 (NH2) Kg/ha. The trend of phosphorus content in study area was NH1< CT<CH<PFC<NH2. The overall average values of nitrogen in the study area varied from 0.123±0.02 % to 0.45±0.02 %.The results showed that CH<CT<NH2<NH1<PFC trend of nitrogen content (%).

The average values of potassium content of both the depths varied from 78.4±47.51kg/ha to 145.6±47.51kg/ha. The trend in potassium content at different forest sites is NH1<PFC<NH2< CH<CT.

Correlation between soil variables

The relationship among soil variables was calculated by pooling data of all five forest sites as follow (Fig. 1.1 -1.4).

Principal Component Analysis

The principal component analysis table 5 reveals that Principal component 1 (PC1) contributed 71.58% (8.59 eigen value) of total variance. PC1 included organic carbon, pH, sand, silt, clay, soil organic carbon and bulk density while Principal Component 2 (PC2) contributed 15.53 % (1.86 eigen value) of total variance and PC2 included nitrogen, phosphorus, moisture content and Water Holding Capacity whereas Principal Component 3 (PC3) contributed only 8.95 % (1.07 eigen value) of total variance and it included potassium (Fig. 2.1). Organic Carbon, Nitrogen, Phosphorus and Sand were observed to show opposite trend to pH, Potassim, Water Holding Capacity, Moisture Content, Silt, Clay and Bulk Density

Table 4: Physico-chemical properties of soil at different forest sites.

Parameters	CT	CH	NH1	NH2	PFC	ANOVAs
Water holding capacity (%)						
0-15cm	115.39±16.62	96.28±3.34	117.15±14.63	102.39±16.39	86.43±24.24	
15-30cm	112.44±12.94	96.34±2.91	107.62±15.78	96.19±14.88	83.96±13.00	
Mean	113.91±2.08	96.31±0.042	112.385±6.73	99.29±4.38	85.19±1.74	0.07
Moisture content (%)						
0-15cm	52.11±7.64	28.74±1.88	51.09±3.10	44.56±6.63	26.88±3.39	
15-30cm	62.62±4.79	37.72±4.57	55.25±3.05	32.82±8.04	32.84±1.39	
Mean	57.36±7.43	33.23±6.34	53.17±2.94	38.69±8.30	29.86±4.21	0.000
Bulk density (gm/cm^3)						
0-15cm	1.00	1.00	0.92	0.89	0.75	
15-30cm	1.02	1.04	0.90	0.96	0.78	
Mean	1.01±0.01	1.02±0.02	0.91±0.01	0.92±0.04	0.76±0.02	-
Organic carbon (%)						
0-15cm	0.85±0.22	0.9±0.28	1.38±0.22	1.25±0.34	1.83±0.07	
15-30 cm	0.65±0.25	0.65±0.22	0.98±0.04	0.9±0.10	1.4±0.24	
Mean	0.75±0.14	0.77±0.17	1.18±0.28	1.07±0.24	1.61±0.30	0.000
Soil organic matter (%)						
0-15cm	1.46±0.37	1.54±0.48	2.37±0.38	2.15±0.58	3.15±0.12	
15-30cm	1.12±0.45	1.12±0.37	1.69±0.07	1.55±0.18	2.40±0.42	
Mean	1.29±0.24	1.33±0.29	2.03±0.48	1.85±0.42	2.77±0.53	0.003
pH						
0-15cm	6.68±0.362	6.57±0.193	6.34±0.109	6.24±0.106	5.91±0.01	
15-30	6.80±0.408	6.73±0.330	6.38±0.116	6.3±0.084	5.96±0.02	
Mean	6.74±0.084	6.65±0.113	6.36±0.028	6.27±0.042	5.93±0.03	0.00
Nitrogen (Kg/ha)						
0-15cm	0.186±0.04	0.14±0.03	0.39±0.03	0.37±0.07	0.47±0.03	
15-30cm	0.14±0.01	0.106±0.02	0.37±0.04	0.36±0.05	0.43±0.03	
Mean	0.163±0.03	0.123±0.02	0.38±0.01	0.36±0.007	0.45±0.02	0.000
Phosphorus (Kg/ha)						
0-15cm	29.10±3.19	31.9±4.24	28.13±2.23	34.69±1.42	32.67±1.32	
15-30cm	29.74±3.36	30.19±3.07	27.52±0.76	32.22±1.03	33±1.43	
Mean	29.42±0.45	31.04±1.20	27.82±0.43	33.45±1.74	32.83±0.23	0.031
Potassium (Kg/ha)						
0-15cm	134.4±83.81	124±52.71	104.53±39.8	134.4±31.67	141.86±59.96	
15-30cm	216.53±65.94	126.93±18.28	95.33±35.03	104.53±32.97	89.6±15.83	
Mean	175.4±58.07	125.46±2.07	99.93±6.50	119.46±21.12	115.73±36.95	0.36

(Fig. 2.2).

MC= Moisture Content; WHC Water Holding Capacity; N- Nitrogen; OC- Organic Carbon; SOM – Soil Organic Matter; K- Potassium; P-Phosphorus. Bulk Den- Bulk Density

The soil of an area is the composition of sand, silt and clay. The soil texture is determined by the relative proportions of these three particles. Loam soil is considered as a balance proportion of sand, silt and clay and suitable for the growth and development of plants. The comparative account of different physico-chemical properties of the soil with earlier reports is presented in table 6 and 7.

Clay-loam and sandy-loam soil were observed in the present study sites (Table 2). The values of sand ranged from 22.75–45.91%, silt 24.77–38-5% and clay 29.49–39.66% in the soil of study sites and these values were almost similar as recorded in earlier investigation by Semwal *et al*., (2009) from the Western Himalaya. Texture is being pivotal characteristic of the soil as it

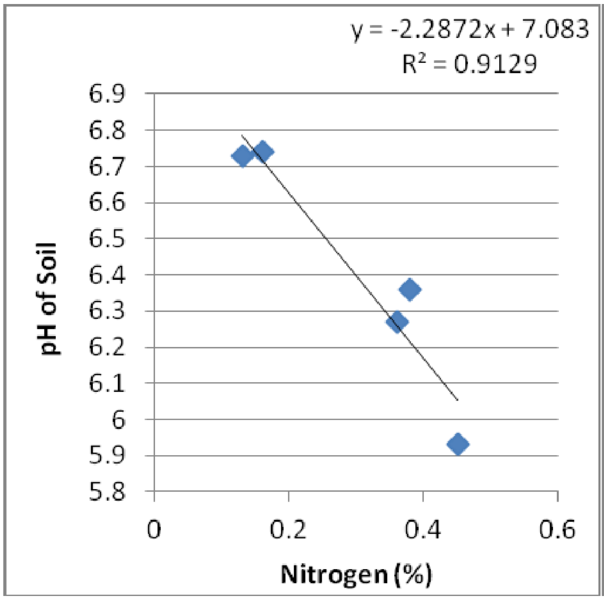

Fig. 1.1

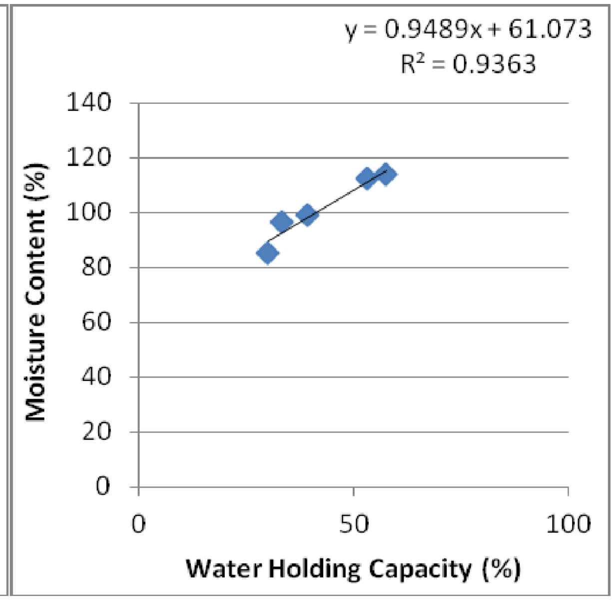

Fig. 1.2

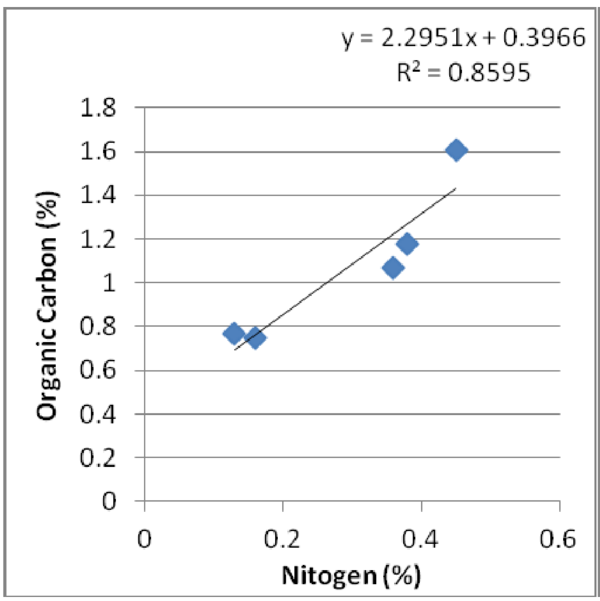

Fig. 1.3

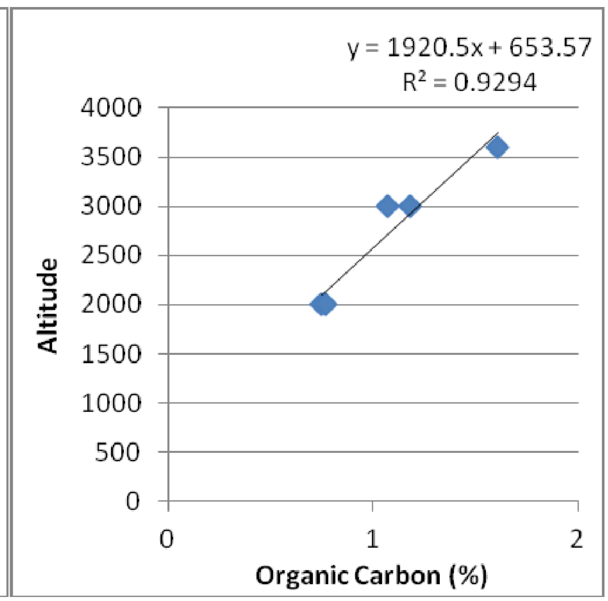

Fig. 1.4

determines absorption and storage of water in the soil as well as provides the volume of aeration which is vital for plant growth thus affecting the fertility of the soil. Texture of the soil also affects the water holding capacity, moisture content and temperature of the soil. In all forest sites, soil texture was clay loam except in PFC site (above timber line) where texture was recorded as sandy clay loam because with the increase in altitude clay content tends to decrease and sand proportion increases, thus, sand content showed a reverse trend. Charan *et al.*, (2013) also observed an increasing trend of sand fraction along an increasing altitude in cold desert (Leh-Laddakh). The sandy soil allows the growth of only those tree species which require low content of moisture, whereas, loam soil mostly supports tree species such as *Abies* sp. (Fir) and *Picea* sp. (Spruce) which have more requirements of nutrients and moisture (Sharma *et al.*, 2010). The loam soils are being medium size textured soil containing more humus and nutrients as compared to sandy soil and have great drainage capacity and infiltration rate than clay soils. Thus, loam soils hold sufficient amount of water, air and nutrients and are worthy porous. Most tree species except a few perform better in sandy loam and clay loam soils as they get sufficient amount of nutrients and adequate water and air supply (Osman *et al.*,2013).

It is evident that the darker colouration of the surface layer of soil is due to presence of high organic matter

Table 5: Principal Component Analysis of Soil Variables.

Principal component	Eigen value	% variance
PC1	8.59042	71.587
PC2	1.8647	15.539
PC3	1.07501	8.9584

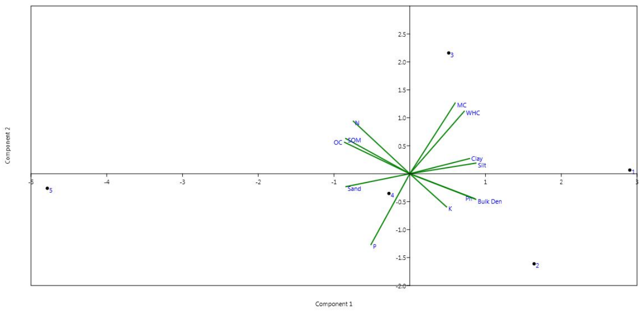

Fig. 2.1 : Biplot graph of Principal Component Analysis of Soil Variables.

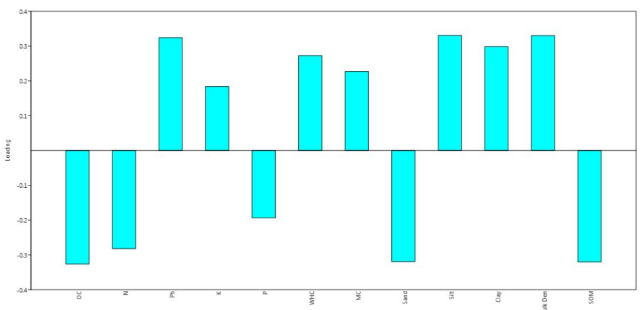

Fig. 2.2 : Loading Graph of Principal Component Analysis of Soil Variables.

(humus, litter, minerals and remains of animals and plants). Soil colour can be linked with quality of the soil. The colour of soil in the present study area showed variation among different forests and depths and it varied from very pale brown to very dark brown (Table 3). Sharma *et al*., (2010b) also observed the soil colour of temperate Himalayan forests and reported that it lies in the range of yellowish brown to dark brown. Usually in all forest sites surface layer of the soil was noticed with dark colour except in lower altitude forest sites (CT and CH) where lower depths were possessing darker brown colour while upper layer showed lighter brown colour. This slight variation in soil colour along the depth may be possible due to the parent material of soil as the soil's parent material accounts for the colour and its pH. The parent material and climate had profoundly affects on the characteristics of the soil (Yang *et al.,* 2008).

The water transmission and water retention characteristics of the soil differ in relation with its texture (Kumar *et al.,* 2002). The water holding capacity among the soils of different sites of the present study ranged from 85.19 113.91% (Table 4). The high clay content was the reason for high value of water holding capacity of the soil. These values are within the range when compared with earlier report of Malik (2014). Water holding capacity was recorded higher in upper depth and in the forest sites where clay content was high. In the present finding low water retention capacity was observed for the PFC forest site which possessed more sand content. Water holding capacity of the soil was found positively correlated with moisture content of the soil (Fig. 1.2).

Table 7: Chemical properties of soil of different parts of Himalaya.

Study Area	Altitude (m amsl)	N (%)	P (Kg/ha)	K (Kg/ha)	OC (%)	SOM (%)	pH	Reference
CWS,H.P. Western Himalaya	1900–3600	0.12–0.45	27.82–33.45	99.93–175.4	0.75–1.61	1.28–2.77	5.93–6.74	Present Study
Pauri,Garhwal Himalaya	1700–1850	0.041–0.109	7.70–23.55	114.24–256.36	0.48–1.68	*	5.24–6.78	Semwal,2006
Central, Himalaya	1500–2200	0.117–0.243	0.10–0.92%	1.30–3.12%	2.01–2.38	*	*	Semwal *et al*., 2009
Tehri, Garhwal	1100–1500	*	24.07–32.77	159.04–203.09	0.15–0.42	*	*	Kumar *et al*., 2010
Kumaon, Himalaya	1800–1900	0.13–0.33	42.12–56	226.19–388.57	1.14–1.40	2.84–5.05	5.5–6.5	Jina *et al*., 2011
Garhwal, Himalaya	1000–2600	0.144–0.306	23.50–27.68	164.10–201.51	0.599–1.064	0.906–1.81	4.90–5.51	Malik,2014

Moisture content of the study area was recorded from 29.86 57.36% table 4 and these values were in the range as per reports of Arya (2014) and Malik (2014) from the IHR. The highest moisture content was observed in the forest sites (CT and NH1). The moisture content was recorded to show significant difference among different forest sites during different seasons and depths. The varying rainfall trend among forest sites at different altitude is one of the major reasons for this significant variation in moisture content. The variation in moisture content can be explained in accordance to rainfall, altitude, aspect and slope. Water retention capacity of soil and water absorbing nature and capability of moisture loving tree species and forest cover had important role to play when discussing the moisture variation at any forest site.

Bulk density is the

Table 6: Physical properties of soil of different parts of Himalaya.

Study Area	Altitude (mamsl)	Sand (%)	Silt (%)	Clay (%)	Moisture Content	Water Holding Capacity	Reference
CWS,H.P. Western Himalaya	1900–3600	22.7–45.91	24.77–38.5	29.44–39.66	29.86–57.36	85.19–113.91	Present Study
Central Himalaya	1500–2200	23.39–39.57	29.00–39.00	30.63–43.02	*	*	Semwal *et al*., 2009
Mandal-Chopta, Garhwal Himalaya	1600–2150	53.67–56.67	26.33–26.67	17–19.67	27–29	69.2–80.41	Sharma *et al*., 2010
Kumaon Himalaya	2100–3500	40.70–48.40	22.80–26.20	27.70–36.70	34.50–54.80	40.00–72.20	Arya, 2014
Garhwal Himalaya	1000–2600	61.59–82.03	1.24–6.71	15.02–32.20	13.65–68.99	40.87–105.80	Malik, 2014

volume-weight relationship of oven dry soil. Bulk density varied from 0.76-1.02 gm/cm^3 in the present study (Table 4). The values of similar range were reported by Sharma *et al*., (2010b) from moist temperate forests valley (Central Western Himalaya) and Khera *et al*., (2001) from mixed forest of Kumaon Himalaya. High bulk density values were recorded at lower altitude forest sites and lower values were reported in high elevation forest sites in the present study. Hanawalt and Whittaker (1976) stated the decreasing trend in bulk density with rise in elevation conforming the findings of the present study.

pH of soil of the study area was recorded as 5.93-6.74 (Table 4). These values are comparatively similar to earlier findings of Semwal (2006), Jina *et al*., (2011). The pH of the soil in different forest sites significantly decreased with increase in elevation. The cause for significant variations in pH of soil among forest sites is the process of acidification which was more in high altitude forest soil. The pH was low in higher altitude forest sites where greater amount of organic carbon was present. Gairola *et al*., (2012) also observed low pH of soil in the forests which had high organic content. The decline in pH can be imputed to release acids to the soil by accumulation and slow rate of decomposition of organic matter (De Hann, 1977). The pH of the study area was slightly acidic in nature. According to Leskiw (2004) slightly acidic nature of forest soils should be there for providing and balancing the sufficient nutrient supply. A fertile soil contains a pH range from 5.5-7.2 and permits the nutrients to be available for the vegetation.

Organic carbon ranged from 0.75-1.61% and soil organic matter recorded from 1.28-2.77% during present study (Table 4). These values are in conformity with the reports of Semwal, (2006) and Jina *et al*., (2011). The soil organic matter was also found to be increasing with increase in elevation (Fig. 1.4) whereas both organic carbon and soil organic matter declined with depths in the present investigation. The soil organic matter is described in relation to carbon decomposition. Jobbagy and Jackson (2000) also suggested the same order of reduction in soil organic carbon with depths. Soil organic matter affects the water retention by lowering evaporation rate whereas rising water infiltration rate (Gairola *et al*., 2012). Increase in soil organic matter with rise in elevation can be attributed due to slow decomposition process of organic remains at higher altitude where low temperature prevailed along with addition of leaf debris to the soil.

In terrestrial ecosystems both organic and inorganic forms of phosphorus are present but available organic phosphorus is primarily used by the plants. According to Murphy (1958) greater amount of phosphorus storage forms are not readily available to plants and one such storage form is phosphoric acid (H_2PO_4) which turn into obtainable at low pH (Soromessa *et al*., 2004). Phosphorus content (kg/ha) values were recorded as 27.82-33.45 kg/ha in the present study table 4 and the values lie within in the range as per Kumar *et al*., (2010).

Potassium helps to plants in performing various vital processes which include regulation of respiration, transpiration, carbohydrates as well as protein synthesis and also the enzymatic actions (Brady, 1996). Drainage and leaching of potassium results in reduction of potassium which ultimately reduces the vegetation of an area (Basumatary and Bordoloi,1992). Potassium content in the present study ranged from 99.93-175.4 Kg/ha table 4 and almost similar range of potassium content was observed by Semwal (2006). However, the potassium content may vary between among forest sites depending upon the parent material and weathering process.

Nitrogen is a crucial element required for the growth and development of the plant as if not available to plants they become stunted. Nitrogen content (%) varied from 0.12-0.45 in present study table 4 which is more or less in similar range as reported by Jina *et al*., (2011) although Semwal (2006) had reported higher values from the forest soil of Pauri Garhwal, Himalaya. The present report recorded that more nitrogen content in the upper layer and comparatively less in lower layer may be due the presence of high organic matter in the upper depth of the soil of the forest. The significant variation in nitrogen content (%) in different seasons and depths were recorded in present report. Nitrogen content could vary significantly due to the different rates of ammonification process in different forest types. The main form of nitrogen available to plant is soil's nitrates which freely and quickly moves with moisture. Nitrogen showed a positively correlation with organic carbon (Fig. 1.3) and a negative correlation with pH (Fig. 1.1) in the present findings. Gairola *et al.,* (2012) also reported positive correlation between nitrogen and organic carbon. Nitrogen and Carbon are closely linked and soil organic matter (animal and plant remains) is considered as the primary source of C and N. Jha *et al*., (1984) also stated that if soil has rich organic matter then its Nitrogen content would also be definitely rich. The rate of nitrogen leaching from the ecosystems and as well as the vitality of the particular plant community is reflected by the nitrogen content present in the soil (Burianek *et al.,* 2013).

Acknowledgement

I am very grateful to Dr. Dinesh Singh Rawat for his contribution and valuable suggestions to complete my research paper.

References

Arya, M.K. (2014). Assessment of Physico-chemical Properties of Soil along Altitudinal Gradients in a Protected Forest in the Kumaun Himalayas, India. *Nature and Science*, **12(2):** 32-37.

Badía, D., A. Ruiz, A. Girona, C. Martí, J. Casanova, P. Ibarra and R. Zufiaurre (2016). The influence of elevation on soil properties and forest litter in the Siliceous Moncayo Massif, SW Europe. *Journal of Mountain Science*, **13(12):** 2155-2169.

Basumatary, A. and P.K. Bordoloi (1992). Forms of potassium in some soils of Assam in relation to soil properties. *Journal of the Indian Society of Soil Science*, **40(3):** 443-446.

Buriánek, V., R. Novotný, K. Hellebrandová and V. Šrámek (2013). Ground vegetation as an important factor in the biodiversity of forest ecosystems and its evaluation in regard to nitrogen deposition. *Journal of Forest Science*, **59(6):** 238-252.

Brady, N.C. and R.R. Weil (1996). Organisms and ecology of the soil. *The nature and properties of soil*, **11:** 328-360.

Bremner, J.M. and C.S. Mulvaney (1982). Nitrogen-Total 1. *Methods of soil analysis. Part 2.Chemical and microbiological properties*, (methodsofsoilan2): 595-624.

Charan, G., V.K. Bharti, S.E. Jadhav, S. Kumar, S. Acharya, P. Kumar and R.B. Srivastava (2013). Altitudinal variations in soil physico-chemical properties at cold desert high altitude. *Journal of soil science and plant nutrition*, **13(2):** 267-277.

De Haan, S. (1977). Humus, its formation, its relation with the mineral part of the soil, and its significance for soil productivity. *Soil organic matter studies*, **1:** 21-30.

Donahue, R.L., R.W. Miller and J.C. Schickluna (1987). *An Introduction to Soil and Plant Growth* 5th edition. Prentice Hall of India Pvt.Ltd., New Delhi.

Gairola, S., C.M. Sharma, S.K. Ghildiyal and S. Suyal (2012). Chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya, India. *The Environmentalist*, **32(4):** 512-523.

Jha, M.N., R.K. Rathore and P. Pande (1984). Soil factor affecting the natural regeneration of silver fir and spruce in Himachal Pradesh. *Indian Forester*, **110(3):** 293-298.

Jina, B.S., C.S. Bohra, L.S. Lodhiyal and P. Sah (2011). Soil characteristics in oak and pine forests of Indian Central Himalaya. *E-Int. Scientific Res. J.*, **3(1):** 19-22.

Jobbágy, E.G. and R.B. Jackson (2000).The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological applications*, **10(2):** 423-436.

Hanawalt, R.B. and R.H. Whittaker (1976). Altitudinally coordinated patterns of soils and vegetation in-the San Jacinto Mountains, California. *Soil Science*, **121(2):** 114-124.

Kaur, H. and M. Sharma (2004). *Flora of Sirmaur, Himachal Pradesh*. Bishen Singh Mahendra Pal Singh.

Mishra, R. (1968). Ecology Workbook p. 244. *Calcutta: Oxford and IBH Publ. Co*.

Labaz, B., B. Galka, A. Bogacz, J. Waroszewski and C. Kabala (2014). Factors influencing humus forms and forest litter properties in the mid-mountains under temperate climate of Southwestern Poland. *Geoderma*, **230:** 265-273.

Leskiw, L.A. (2004). Land capability classification for forest ecosystems in the oil sands region.Alberia environmental protection, *Edmonton*.

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

Kumar, S., J.C. Sharma and I.P. Sharma (2002). Water retention characteristics and erodibility indices of some soils under different land uses in North-West Himalayas. *Indian Journal of Soil Conservation*, **30(1):** 29-35.

Kumar, S., M. Kumar and M.A. Sheikh (2010). Effect of altitudes on soil and vegetation characteristics of Pinus roxburghii forest in Garhwal Himalaya. *J. Adv. Lab. Res. Biol.*, **1(2):** 1-4.

Malik, Z. (2014). *Phytosociological Behaviour, Anthropogenic Disturbances and Regeneration Status Along An Altitudinal Gradient In Kedarnath Wildlife Sanctuary (KWLS) And Its Adjoining Areas*. Ph.D. Thesis submitted to HNB Garhwal University, Srinagar Garhwal, Uttarakhand.

Morwin, H.D. and P.M. Peach (1951). Exchangeability of soil potassium in and, silt and clay fractions as influenced by the nature of complementary exchangeable cations. *Soil Science Society of America Journal*, **15:** 125-128.

Oslen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate US Dep. *Agric. Cire*, 939.

Osman, K.S., M. Jashimuddin, S.S. Haque and S. Miah (2013). Effect of shifting cultivation on soil physical and chemical properties in Bandarban hill district, Bangladesh. *Journal of forestry research*, **24(4):** 791-795.

Pandeya, S.C., G.S. Puri and J.S. Singh (1968). Research methods in plant ecology. *Research Methods in Plant Ecology.*

Paudel, S. and J.P. Sah (2003). Physiochemical characteristics of soil in tropical sal (*Shorea robusta* Gaertn.) forests in eastern Nepal. *Himalayan J. Sci.*, **1(2):**107-110.

Semwal, S. (2006). *Studies on Phytosociology, Diversity Patterns and Competition along an Altitudinal Gradient in a part of Lesser Himalaya in Garhwal, Uttaranchal.* D.Phill. Thesis, HNB Garhwal University, Srinagar (Garhwal), Uttarakhand, India.

Semwal, D.P., P.L. Uniyal, Y.M. Bahuguna and A.B. Bhatt (2009). Soil nutrient storage under different forest types in a part of central Himalayas, India. *Ann. For*, **17(1):** 43-52.

Sharma, C.M., N.P. Baduni, S. Gairola, S.K. Ghildiyal and S. Suyal (2010).Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India. *Forest Ecology and Management*, **260(12):** 2170-2179.

Sharma, C.M., S. Gairola, S.K. Ghildiyal and S. Suyal (2010b). 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*, **26(2):** 117-129.

Soromessa, T., D. Teketay and S. Demissew (2004). Ecological study of the vegetation in GamoGofa zone, southern Ethiopia. *Tropical Ecology*, **45(2):** 209-222.

Subramani, S.P., K.S. Kapoor and G.S. Goraya (2014). Additions to the floral wealth of Sirmaur District, Himachal Pradesh from Churdhar Wildlife Sanctuary. *Journal of Threatened Taxa*, **6(11):** 6427-6452.

Walkley, A. (1947). An estimation of methods for determining Organic Carbon and Nitrogen in soils.*Journal of Agricultural Science*, **25:** 598-609.

Yang, Y., J. Fang, Y. Tang, C. Ji, C. Zheng, J. He and B. Zhu (2008).Storage, patterns and controls of soil organic carbon in the Tibetan grasslands. *Global Change Biology*, **14(7):** 1592-1599.