



Status Of Soil Chemical Properties As Affected By Seasonal Variation In The Sub-Tropical Forest Zone Of Western Himalaya

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Abstract: The forest ecosystem plays a crucial role in maintaining the inter-related complexity between vegetation and soil. Anthropogenic pressure, not only reduces the forest biodiversity but also leads to the deterioration of the soil quality. Thus, it is essential to understand the soil condition to promote the growth of the forest ecosystem. The current study analyzes the physicochemical properties of soils under pine forest stand, by collecting the samples at three different soil depths (0-10 cm, 10-20 cm, and 20-30 cm). The study mainly focused on the available soil cations (sodium, calcium, and potassium) because they act as an immediate source for vegetation. The main objective of the present study was to determine the variation in soil available cations (K^+ , Ca^+ , and Na^+) concentration along with the soil depth during different seasons. Seasonal alterations occurred in the soil's chemical attributes, influenced by ecological changes occurred in vegetation. Results showed seasonal fluctuations in soil pH, EC, and soil cations during the study period. Results also showed that variation in potassium and calcium concentration during different seasons does not differ significantly on the other side variation in sodium concentration differs significantly during different seasons. Sodium and calcium content also showed significant differences among the different sites.

Key Words: Forest ecosystem, physicochemical properties, available cations, seasonal variation.

Introduction

Soil is one of the most precious natural resources, which provides a medium for plant growth and development. Soil act as a nutrient source for the plants to carry out different environmental processes and also provide an anchorage for the terrestrial ecosystem (Gairola et al. 2012; Li et al. 2013; Chandra et al. 2016; Pandey et al. 2018). The variation in soil type and its development is controlled by lithology, topography, and climate of the study area (Deshmukh 2012; Saha et al. 2018). At present, the majority of our land resources are degraded due to increased industrialization and urbanization. Thus, generate tremendous pressure on soil quality, productivity and also govern the soil toward degradation

(Deshmukh 2012; Olojugba and Fatubarin 2015; Kharal et al. 2018). Human pressure influenced the soil properties which include soil porosity, soil structure, aggregate stability, organic matter, soil pH, soil EC, soil microbes, nutrient availability, and nutrient cycling (Olojugba and Fatubarin 2015). To meet the global requirements, it becomes important to utilize the soil potential wisely. Hence, it is essential to maintain soil health for sustainable productivity and management against the fast escalating pressure on soil (Deshmukh 2012; Kharal et al. 2018).

The indicators, which help in monitoring the soil quality can be grouped into three categories, these



are physical, chemical, and biological indicators (Olojugba and Fatubarin 2015). The chemical properties of soils (pH, EC, plant minerals, cations, etc.) play an important role in determining the soil quality and its retention potential (Deshmukh 2012). Soil cations (Na⁺, Ca⁺, and K⁺) are affected by biogeochemical cycling, leaching, and parent material of soil of the region thus, maintaining and conserving the soil is essential (Jobbágy and Jackson 2004; Blank 2010; Takoutsing et al. 2016; Kharal et al. 2018).

Both biotic (vegetation) and abiotic factors (weather and topography) cause complex interaction with soil properties thus, a comprehensive understanding of variation in soil properties is necessary to determine (Chandra et al. 2016; Saha et al. 2018). Within the ecosystem, seasonal variation can be categorized by different ecological phenomena and showed impact on both biotic and edaphic factors hence causing complex interaction (Olojugba and Fatubarin 2015). To determine the quality of forest soil, it is essential to determine physicochemical attributes of soil including soil cations (Li et al. 2013). The current study was carried out to analyze the chemical characteristics of soil and their variation. The study also observed the influence of seasonal variation on cations selectivity (Na⁺, Ca⁺, and K⁺) in the forest soil of the study area. The Himalayan region is a complex ecosystem with huge variations in topography, climate, and edaphic conditions (Gairola et al. 2012; Pandey et al. 2018) thus, the soil of the Himalayan forest often showed more variation in its properties. In the present course of investigating a relationship between cations and seasonal variations was analyzed under the Pinus (*Pinus roxburghii*) forest stand of Himachal Pradesh, India, which showed dominance and spread over a large part of the study area. Pinus is regarded as stress-tolerant species which can grow on low nutrient-rich soil, compare to other Himalayan species

(oaks and sal), and form an open canopy (Singh and Singh 1987). *Pinus roxburghii* is a shallow-rooted and large evergreen conifer tree found between 800 to 1700 msl. In these forests, the frequency of forest fire occurrence is high (Singh and Singh 1987; Naudiyal and Schmerbeck 2017), mainly during the dry season of the year which further influences the chemical composition of the soil. Due to this (forest fire) and other influential human activities, the productivity of forests was falling dramatically (Pant and Tiwari 2014). The present study mainly focused on the physicochemical attributes of soil along with the soil depth under *Pinus roxburghii* forest stand. The study also observed the seasonal dynamics of soil available cations in the study area. The knowledge will be helpful to understand the importance of these forests in the conservation and protection of soil under immense human pressure.

Materials and Methods

Site description

The present study was carried out under Pinus forest stand located in Bilaspur district of Himachal Pradesh, India. It is situated between 31° 12' 30" and 31° 35' 45" north latitudes and 76° 23' 30" and 76° 55' 40" east longitudes in the north-western portion of Himachal Pradesh with an altitude ranging from 350 to 1500 m. The study area is hilly terrain with a sub-tropical climate and with annual average rainfall is about 1106.28 mm. The weather conditions are sub-humid to humid with cold winter and hot summer and temperature range between 5 °C to 37 °C although sometimes during summer it can go up to 44 °C The seasonal climate is characterized by three different seasons featured commonly in the study area i.e. winter, summer, and rainy.

Plot layout and soil sampling

The study site was covered with an all-aged mono-specific natural forest of *P. roxburghii*. At each forest site, seven permanent plots (20 m ×



20 m) were established randomly to carry out the soil sampling during different seasons (winter, summer, and rainy). A soil corer was used to collect the soil samples at three different soil depths; 0-10 cm, 10-20 cm, and 20-30 cm. Soil samples were kept in well-labeled plastic bags and were taken to the laboratory for further analysis.

Chemical analysis

The soil samples were air-dried and sieved by passing through 2 mm mesh for further analysis.

The soil pH and EC was determined with a 1:2.5 solution (soil: distilled water). The concentration

of available potassium, calcium, and sodium was measured using the flame photometric (systronics-128) and the extraction was carried out by using ammonium acetate. Physicochemical parameters and their measurement methods were given in Table 1.

Statistical analysis

Data collected from four forest sites, to investigate the variation in soil properties were analyzed by analysis of variance (ANOVA) using Excel (Microsoft Corp., Seattle, WA, USA) and correlation coefficient. The data in tables represent averages \pm SE (Standard Error).

Table 1. Physicochemical parameters and their measurement methods

S.N.	Parameters	Unit	Methods/References
1.	Physical		
	Soil texture		Brady and Weil, 2002
	Bulk density	g cm ⁻³	Wilde et al., 1979
	Soil moisture	%	Kadam and Shinde, 2005
2.	Chemical		
	Soil pH		Jackson, 1973
	Soil EC	Ds m ⁻¹	Jackson, 1973
	Available K (as K ₂ O)	Kg ha ⁻¹	Hanway and Heidel (1952)
	Available Ca	Kg ha ⁻¹	Ammonium acetate (Jackson 1967)
Available Na	Kg ha ⁻¹	Ammonium acetate (Jackson 1967)	

Results and Discussions

Soil physical characterization

Bulk density ranged from 1.06 g cm⁻³ to 1.27 g cm⁻³ (Table 2) and it does not show any regular trend during different seasons. Bulk density at different forest sites showed an increasing trend with increasing soil profile (Mora et al. 2014). The highest bulk density was observed at site III and the lowest bulk density was observed at site IV. The bulk density of the study area differs

significantly along with the soil depth and also among different sites.

Soil moisture content among the different forest sites ranged from 5.20 % to 10.23 % (Table 2). The moisture content does not follow any specific trend along with the soil depth. Although it was observed maximum at the surface layer of soil at all the forest sites except site IV (Tyagi et al. 2013). Alike bulk density, moisture content was observed highest at site III and lowest at site IV. Soil moisture content does not differ significantly



along with the soil depth while among the sites it differs significantly. Soil moisture plays an important role in inducing variation in soil respiration along with some hydrological factors

(Tyagi et al. 2013; Wangluk et al. 2013). It acts as an indicator of changing environmental conditions because directly influenced by physical factors (Tyagi et al. 2013).

Table 2. Some physical characteristics of the soil of forest sites

		Site I	Site II	Site III	Site IV
Bulk density	0-10 cm	1.09±0.06	1.11±0.02	1.15±0.06	1.06±0.01
	10-20 cm	1.17±0.04	1.16±0.04	1.23±0.07	1.12±0.02
	20-30 cm	1.27±0.09	1.22±0.09	1.26±0.05	1.15±0.04
Soil moisture	0-10 cm	9.24±0.79	9.45±1.08	10.23±1.09	5.20±0.56
	10-20 cm	7.70±1.01	7.87±1.05	9.22±0.86	6.21±1.07
	20-30 cm	8.33±1.13	7.21±1.05	9.23±0.97	5.42±0.45
Sand	0-10 cm	28.45±0.70	43.24±0.93	35.57±0.46	42.29±1.46
	10-20 cm	23.57±0.71	36.06±1.50	31.38±0.64	37.78±0.10
	20-30 cm	27.93±0.33	27.86±1.19	30.59±0.52	38.00±1.58
Silt	0-10 cm	25.16±0.16	19.22±0.41	31.12±0.40	17.96±0.33
	10-20 cm	33.69±0.60	24.61±2.56	24.83±0.92	17.04±0.74
	20-30 cm	23.01±0.81	25.56±0.64	24.63±1.30	17.89±1.10
Clay	0-10 cm	46.39±0.82	37.54±1.34	33.31±0.86	39.75±1.37
	10-20 cm	42.74±0.12	39.33±1.15	43.78±1.00	45.19±0.74
	20-30 cm	49.06±0.53	46.58±1.36	44.78±1.33	44.11±2.57

Bulk density (g cm⁻³), soil moisture (%), sand (%), silt (%), and clay (%).

The soil texture of the study area varies from silty clay (at site I and site III), silty clay loam (at site II) to clay loam (at site IV) results can be related to Semwal et al. 2009. Among the four forest types the percentage (%) of sand, silt, and clay ranged from 23.57 to 43.24, 17.04 to 33.69, and 33.31 to 49.06 respectively (Table 2). Sand, silt, and clay content of the study area do not differ significantly along with the soil depth and only the sand content differs significantly among the sites of the study area.

Soil pH is an important parameter as it ensures the availability of plant nutrients in the soil (Deshmukh, 2012). The value of soil pH ranged from 6.47-7.25, 6.1-6.9, 5.99-7.12, and 6.56-7.54 for site I to site IV respectively (related to Pandey et al. 2018) (Fig. 1). The highest value of soil pH was observed at site IV and the lowest was

observed at site III. Soil pH does not show any specific pattern during different seasons at different sites. Soil pH was found highest in the winter season at site I and site IV (Mehta et al. 2017), while it was found highest during summer and rainy season at site III and site II respectively. Soil pH reflects the physicochemical properties of soil as it is directly related to the accumulation of extractable sodium and calcium carbonate (Takoutsing et al. 2016). Soil pH showed increment with the increasing soil depth (Pal et al. 2013; Olojugba and Fatubarin, 2015) this may be due to the leaching of bases, high rainfall, and vegetation type of the study area. Low pH was recorded in the undisturbed natural forest when compared with the disturbed forest ecosystem (Kharal et al. 2018). High storage and low decomposition rate of organic matter also reduce



the soil pH. In the study area, soil pH differs significantly among the different seasons and sites but not along with the soil depth.

Soil EC values for different sites ranged from 43.67-172.67 $\mu\text{S cm}^{-1}$, 42.67-228.67 $\mu\text{S cm}^{-1}$, 35-263.67 $\mu\text{S cm}^{-1}$, and 82.67-157.33 $\mu\text{S cm}^{-1}$ from site I to Site IV respectively (Kumar et al. 2021) (Fig. 2). Both the highest and lowest value of EC was recorded at site III. Soil EC does not show any specific pattern during different seasons at different sites. EC was found highest during the summer season at site I and site III (Mehta et al. 2017), while it was found highest during the rainy and winter season at site II and site IV respectively. Soil EC does not differ significantly among the different seasons, soil depth, and sites.

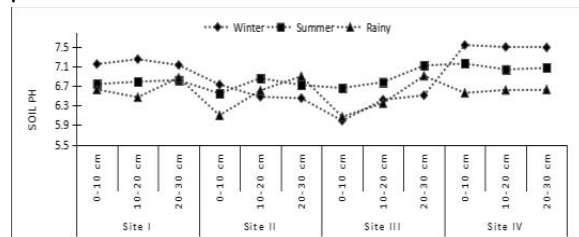


Fig. 1. Soil pH variation at different sites during different seasons

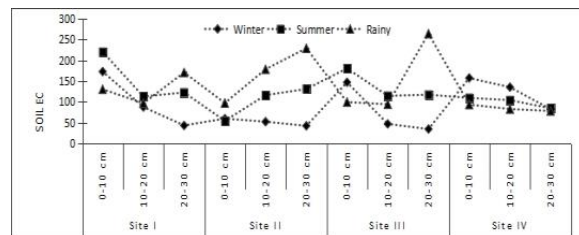


Fig. 2. Electrical conductivity ($\mu\text{S cm}^{-1}$) variation at different sites during different seasons.

Potassium is one of the most important nutrients which balances the water and chemicals in plants for their proper functioning. Its deficiency can result in stunted growth and weak stem in plants (Gairola et al. 2012). The potassium content, in the forest soil dominated by Pinus, was observed and it ranged from 71.16-164.75 kg ha⁻¹, 66.02-144.62 kg ha⁻¹, 40.74-118.64 kg ha⁻¹, and 54.01-

135.04 kg ha⁻¹ for site I to site IV respectively (Fig. 3). Similar results were observed by Saha et al. (2018). Along with the soil depth the potassium content was found highest at 0-10 cm under all the forest sites and its concentration decreases with increases in soil depth and it can be related to the organic form of nutrients which are present in a high amount at the soil surface (Lozano-Garcia et al. 2011; Pal et al. 2013). Vegetation extracts the nutrients from the soil and recycled them through litterfall in the soil (Kharal et al. 2018). Site I showed the highest value for potassium among all the sites. Two main factors which reduce the potassium content are leaching and drainage, which damage the vegetation severely (Kharal et al. 2018). The results on available potassium content can be related to Gairola et al. (2012), Li et al. (2013).

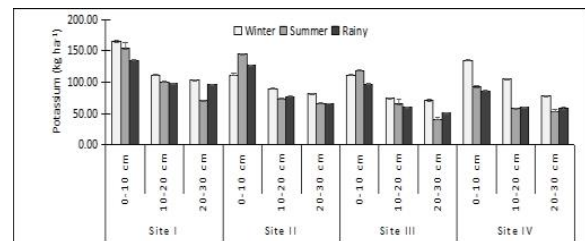


Fig. 3. Available potassium (kg ha⁻¹) variation at different sites during different seasons.

The concentration of potassium varied with different seasons and it was found highest during the winter season at site I and IV, while at Site II and III, it was found highest during the summer season only at the surface layer (Blank, 2010; Mehta et al. 2017). The increase in potassium content during the winter season is due to the shift in soil equilibrium conditions because of low-temperature situations. The available potassium content of the study area differs significantly along with the soil depth but not during different seasons and sites.

Calcium is an essential plant mineral that helps in regulating plant growth and productivity as it is the primary constituent of biomass in plants.



Sources like soil mineral and organic-rich forest floor make calcium available to the plant root system. Generally, calcium deficiency was not found in trees, although it can be seen under managed conditions (Adams et al. 2000; Pal et al. 2013).

The concentration of calcium in soil was ranged from 2465.09-3004.09 kg ha⁻¹, 1273.92-1548.12 kg ha⁻¹, 1102.86-1854.38 kg ha⁻¹, and 1586.65-2010.57 kg ha⁻¹ for site I to site IV respectively (Fig. 4). The high concentration of calcium may be due to the rich limestone present in the parent material of the soil (Kumar et al. 2021). Among the four forest sites, calcium content was found highest at site I at all the soil depths during all the seasons. Soil calcium does not show any specific trend along with the different seasons and along with soil depth. The leaching process and input sources of calcium are the two main factors that affect calcium concentration. Fluctuation in calcium content has a direct implication on the forest ecosystem, thus there is concern about the long-term productivity of forests (Lawrence et al. 1997; Adams et al. 2000). Available calcium of study area differ significantly among the different sites but not along with the soil depth and seasons.

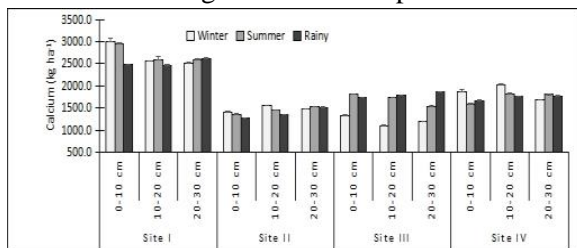


Fig. 4. Available calcium (kg ha⁻¹) variation at different sites during different seasons.

Sodium is an essential element for plant growth and its concentration in the soil acts as an indicator of salinity or alkalinity. The deficiency of sodium is not found in soil but its excessiveness can generate a severe effect on the ecosystem. It causes soil sterilization by affecting both plants and microorganisms which leads to

plant damage and death (Lozano-Garcia et al. 2011).

The sodium content of the soil was estimated under four different forest sites and it was found highest at site I. The concentration of sodium in the soil was ranged from 88.28-140.31 kg ha⁻¹, 56.36-131.77 kg ha⁻¹, 66.02-109.84 kg ha⁻¹, and 63.14-125.33 kg ha⁻¹ for site I to site IV respectively (Fig. 5). Sodium was observed highest during the winter season for all the forest sites, while sodium does not form any specific trend along with the soil depth. According to some previous studies (Lozano-Garcia et al. 2011; Deshmukh, 2012) sodium increases along with the soil depth and is found more abundant at the subsurface level than the surface level of the soil. When compared with other cations (potassium and calcium) sodium is considered as a less essential element although its importance cannot be underestimated. The available sodium content of the study area differs significantly among the different seasons and sites but not along with the soil depth. Blank (2010) also suggests that the availability of sodium was significantly affected by seasons.

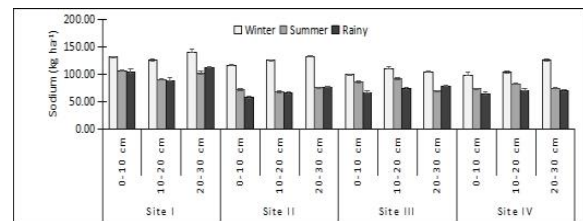


Fig. 5. Available sodium (kg ha⁻¹) variation at different sites during different seasons.

Soil pH act as an indicator, which forms an equilibrium between soil acidity and the cation elements (such as calcium, potassium, and sodium). Soil microbial activity and plant growth are severely affected by soil pH in any ecosystem. Soil pH showed a positive correlation with sand, clay, soil EC, potassium, calcium, and sodium (Table 3). At high pH, calcium displaces potassium from the clay and facilitates its



availability to the plants. Both soil pH and EC are also influenced by many factors and the lab test only indicates the value at the time of sampling on the other side seasonal variation provides an idea about their fluctuation and also enhances the accuracy of data. Soil EC showed a positive correlation with sand, soil pH, potassium, and calcium (Table 3). In the current study pH and EC does not show any specific trends during different seasons at different forest sites.

Comparing the surface and sub-surface layer of soil, different soil properties showed fluctuation

in concentration and no specific trend was observed. Although the surface layer displays the highest value for electrical conductivity and potassium (Nguetnkam et al. 2011) and the subsurface layer shows a high value for bulk density and soil pH minor fluctuation can also be observed. Soil base cations were found in the following order: $Ca^+ > K^+ > Na^+$. Calcium showed a positive correlation with soil moisture, silt, clay, soil pH, EC, potassium, and sodium (Table 3).

Table 3. Correlation (*R* values) between different soil properties under forest sites

	<i>Bulk density</i>	<i>Soil moisture</i>	<i>Sand</i>	<i>Silt</i>	<i>Clay</i>	<i>Soil pH</i>	<i>Soil EC</i>	<i>Potassium</i>	<i>Calcium</i>	<i>Sodium</i>
Bulk density	1									
Soil moisture	0.31	1								
Sand	-0.59	-0.29	1							
Silt	0.32	0.56	-0.71	1						
Clay	0.45	-0.25	-0.57	-0.18	1					
Soil pH	-0.42	-0.74	0.14	-0.52	0.42	1				
Soil EC	-0.81	-0.17	0.25	-0.06	-0.28	0.37	1			
Potassium	-0.62	0.32	0.07	0.16	-0.29	0.11	0.6	1		
Calcium	-0.05	0.02	-0.59	0.28	0.50	0.49	0.36	0.47	1	
Sodium	0.31	0.19	-0.73	0.31	0.66	0.21	-0.03	0.30	0.86	1

Soil showed more selectivity for potassium ions than sodium ions, but at low temperature, the selectivity for sodium was increased (Blank et al. 2010) thus, sodium was observed high during the winter season. Sodium showed a positive correlation with bulk density, soil moisture, silt, clay, soil pH, potassium and calcium (Table 3). Due to the soil degradation, the concentration of Na^+ also gets enhanced (Nguetnkam et al. 2011). Soil moisture fluctuation also reduced the mobility of sodium to some extent (Lozano-Garcia et al. 2011). In soil sodium and potassium ions are fixed on soil particles and can be easily

exchanged with other cations and renew the soil condition (Lozano-Garcia et al. 2011). Both of these elements have a monovalent charge and show high mobility in plants and soil as compared to the other cations. Although potassium possesses a stronger affinity with the exchange complex compared to sodium, thus experiences a reduction in leaching, this can be associated with the plantation (Jobbagy and Jackson 2004). Potassium showed a positive correlation with soil moisture, sand, silt, soil pH, EC, calcium, and sodium (Table 3). The high concentration of



available potassium can also be related to the deep root system of the forest trees.

Forest fire burning is credited to an increase in soil pH however, there is a reduction in the transfer of biomass nutrients to the soil due to the limited breakdown of organic matter and ash complexes. Although calcium and potassium are returned primarily through residual ash (Shimrah et al. 2015). Pedogenic processes of soil were also affected by cations concentration. According to Richards (1954) soil that contains more extractable cation requires special attention. Plants utilize the nutrients from the soil and recycled them to the soil again by litterfall. The transport of nutrients in the soil is not only affected by plant uptake but also through the process of leaching (James et al. 2016). Although the reduction in available potassium concentration is mainly linked with the biological uptake than the leaching. The data of soil properties also vary due to their physiographic situations. The soil of the study area is also subjected to severe soil erosion conditions which can be reduced by enhancing vegetation cover. As the area is a hilly terrain extra care should be taken for the conservation of the region. Thus the concept of forest protection and conservation becomes more important. The current study strongly advocates the protection of pine forests in the region to protect the Himalayan ecosystem.

Conclusion

The current study focuses on the importance of the forest ecosystem in transforming the edaphic conditions of the soil which is not only affected by the forest stand, dominant species, forest type, topography, slope but also through the micro-climatic environment including soil health and type. In the current biogeographic stand of *Pinus*, the nutrient availability was adequate although the fluctuation can also be observed in this nutrient content. Therefore protection, enhancement of the pine forest is important as it

can also grow in low soil nutrient conditions and also maintain its microclimatic. This indicates the potential of the *Pinus* forest to improve the soil health conditions in the region.

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