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INVESTIGATING THE CONNECTION BETWEEN SOIL RESPIRATION AND OAK FOREST DENSITY CLASSES

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Abstract: Soil is a vital trace element in terrestrial ecosystems, and understanding its fertility status is essential for plant growth. This study investigates the nutrient status of soil and its relationship with different density classes of Oak forests in Uttarakhand, India. The sites were selected from Dehra Dun, Pauri Garhwal, and Tehri Garhwal districts, with varying altitude, latitude, and longitude. Soil samples were collected up to a depth of 0-30 cm in each area, with seasonal sampling conducted. Results revealed that soil pH was mildly acidic in dense oak forests, followed by moderate and open forests. An increase in soil nutrients was observed with the increasing density of Oak forests, and nutrient availability was higher in dense forests compared to moderate and open oak forests. This trend was consistent across all selected oak forest density classes. A correlation was found between soil physicochemical and biological properties under different density classes and seasons (winter, summer, monsoon). The pH value and bulk density were negatively correlated with soil organic carbon, available nitrogen, phosphorus, exchangeable potassium, bacterial colony, microbial biomass carbon, and soil respiration. The soil pH was acidic in the upper horizon, and its acidity increased with decreasing density classes. The study also found that high humus content was present in dense forest soils, with microbial biomass carbon negatively correlated with phosphorus during winter and summer seasons. In the monsoon season, soil pH was significantly negatively correlated with soil organic carbon, available nitrogen, phosphorus, exchangeable potassium, bacterial colony, microbial biomass carbon, and soil respiration. Furthermore, these soil properties were positively correlated with each other. The analysis showed that higher tree density in oak forests resulted in increased nutrient values, with dense forests producing more nutrients than moderate and open forests. A positive correlation was found between the density classes (dense>moderate>open oak forest), while a negative correlation was observed with soil pH and bulk density, which increased with decreasing density classes.

Keywords: soil fertility, nutrient status, Oak forests, Uttarakhand, India, soil pH, soil nutrients, soil physicochemical properties, microbial biomass, humus content, soil respiration, tree density.

Introduction

The Himalayan moist temperate forest extending from 1500 to 3000 m amsl in the western and central Himalayas are characterized by extension oak conifer and other various mixed forest oak forest (*Quercus leucotricophora*) and pine (*pinus roxburgnii*). The role of forests has a great impact on the global biogeochemical cycles and in

particular, the carbon cycle. Larger parts of the global C stock are stored in forest ecosystems. Forest play important role for decrease the atmospheric CO_2 in terrestrial ecosystem. Forest play as source and as sink. Forest trapped the atmospheric the carbon dioxide trapped in soil through leafs, rain fall this atmospheric carbon dioxide are decomposed by the process of soil respiration and root respiration. Micro organism also play important soil in decomposition of organic matter and increase the fertility of the soil. Plant material and animal wastes available on the ground, decompose and release nutrients to the soil solution. These nutrients may undergo further transformations in organic and inorganic forms which may be enabled by soil microorganisms. (Raina and Gupta, 2013). Soil microorganisms mineralize nutrients via organic matter decomposition. The living microbial cells comprises of 1% to 5% (w/w) of the total organic carbon, and 1% to 6% of the total organic nitrogen (Jankinson and Pawlson, 1976). The SOC under natural Oak forest was 87.69 t ha^{-1}, whereas SOC pool was 44.63 t ha^{1} under barren land near the Oak forest (Kumar and Gupta ,2017). Soils can act as sinks or as a source for carbon in the atmosphere depending on the changes happening to soil organic matter. Influence of environmental factors to microbial population and microbial biomass plats an important in nutrients cycling in an ecosystem. Soil physicochemical properties characteristic also has great impact on microbial biomass and microbial activity can be used to measure soil quality. Soil is dynamic system in which the soil solution is the medium of physical, chemical and biological processes in soil environments. Soil solution is in dynamic equilibrium with minerals, organic matter, microorganisms and soil atmosphere. Thus it is the bottle neck of transformation and transport of vital and detrimental molecules and ions in the ecosystem (huang; 2000). Purpose of this study to known that the physicochemical and biological properties influence soil quality and productivity with different density classes of oak forest. Seasonal changes in soil microclimate play an important role in significant seasonal differences in soil respiration rate. Several workers (Raich and Schlesinger 1992; Singh and Gupta 1977; Laishram et al.2002; Bijayalaxmi and Yadava 2008).

METHODOLOGY

The study site was selected of oak forest in different density classes in three districts of Uttarakhand. The sites were selected from Dehra Dun, Pauri Garhwal and Tehri Garhwal district of Uttarakhand in different altitude, Latitude and longitude. The region was selected with help of GIS division of Forest Research Institute Dehra Dun. The sites were selected by using GPS points. Chakrata forest division (Dehra dun), dense forest lies between (altitude 1900 latitude N30º40’35.5” and longitude E077º51’47.1”), moderate forest altitude lies (Altitude 1934, latitude N30º40’43.4” longitude E077º51’58.0”) and open forest lies (altitude 1568 latitude N30°29’36.0” longitude E077°51’23.0”), Lansdowne forest division (Pauri Garhwal) it lies in dense forest (altitude 1744mt latitude29º50’21.1” and longitude E-78º41´13.8”), moderate forest (altitude1768mt, latitude N-29º50’42.5”, longitude E078º10’13.0”) and open forest (altitude 1618mt latitude N30º25’35.20 longitude E078º41’35.5”). Similarly, in Itarna forest division it lies (altitude 1381mt latitude N30º25’35.20” and longitude E078°29’17.08”), moderate forest (altitude 1945mt latitude N30º24’68.10”, longitude E078º29’83.94”) and open forest (altitude1763mt latitude N30.21’02.64” longitude E078°29’94.41”). Area under oak forest of different density classes were visited and systematic random sampling was applied for selection of sites in each land use and geographical coordinates and altitude of the sampling sites were recorded by GPS. 3 samples were randomly collected for physico-chemicals

estimation and 3samples were collected for bulk density and coarse fragment estimation from each sampling sites. In all 9 sampling sites were selected and 81 soil samples were collected for physic-chemical and biological properties soil sample was taken from depth of 0-30cm with the helps of augur. The seasonally sampling was done. The bulk density 81sample was taken with help of core sampler (Jackson, 1973). The soil organic carbon was estimated by Walkley and Black method (1934) method as modified by Walkley (1947). The soil pH value by Jackson (1973). The soil available nitrogen was estimated by alkaline potassium permanganate method (Subbiah and Asija, 1956) and available P was determined by Olsen sodium bicarbonate extraction (Olsen and Dean, 1965). The exchangeable K was determined by flamephotometer (Jackson,1973). The data for SOC pool was calculated by using following equation given by IPCC Good Practice Guidance for LULUCF (IPCC, 2003). Soil bacterial was count by using Cloney Counter. Soil respiration measured by soil respiration meter EGM-4. Soil biomass carbon was estimated following chloroform fumigation extraction method as described by Jenkinson and Powlson (1976) and modified by Vance et al (1987).

Sample plots

There were 9 number of sampling sites in dense, moderate, open forest. The sites were circular in shape, and the sizes varied according to depth i.e 0-30cm. Field measurement was done by systematic sampling. Sample were collected from 0-30cm depth for organic carbon and separate soil sample were collected depth 0-30cm for bulk density with help of core sampler.6 sample were collected from each density classes. 54 soil sample were collected in each district in one season. 162 sample were collected from three season (summer, rainy and winter season).

Table 1: General description of study area

S.No	Forest Division	Forest Type (Oak forest)	Elevation (mts.)	Latitude	Longitude
1.	Lansdowne	Dense forest	1744	N-29º50’21.1”	E-78º41´13.8”
		Moderate forest	1768	N-29º50’42.5”	E-078º10’13.0”
		Open forest	1618	N-29º50’04.6”	E-078º41’35.5”
2.	Itarna	Dense forest	1381	N30º25’35.20”	E078°29’17.08”
		Moderate forest	1945	N30º24’68.10”	E078º29’83.94”
		Open forest	1763	N30.21’02.64”	E078°29’94.41”
		Dense forest	1900	N30º40’35.5”	E077º51’47.1”
3.	Chakrata	Moderate forest	1934	N30º40’43.4”	E077º51’58.0”

		Open forest	1568	N30°29’36.0”	E077°51’23.0”

In addition to this, Figure-1 (a)-(d) demonstrates the area map of the sampling sites.

Fig. 1(a) Area map of Uttarakhand

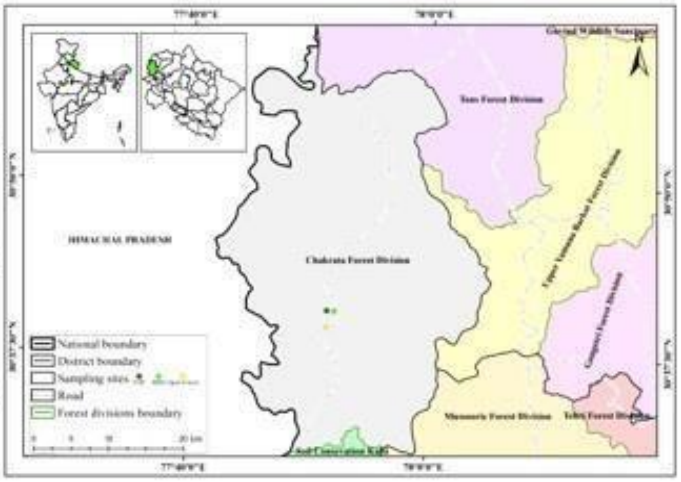

Fig. 1(b) Area map of Chakrata

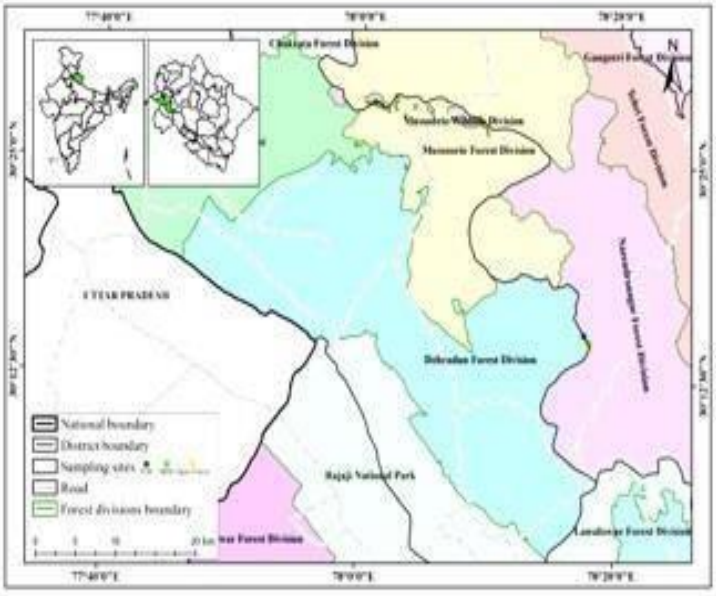

Fig. 1(c) Area map of Itrana

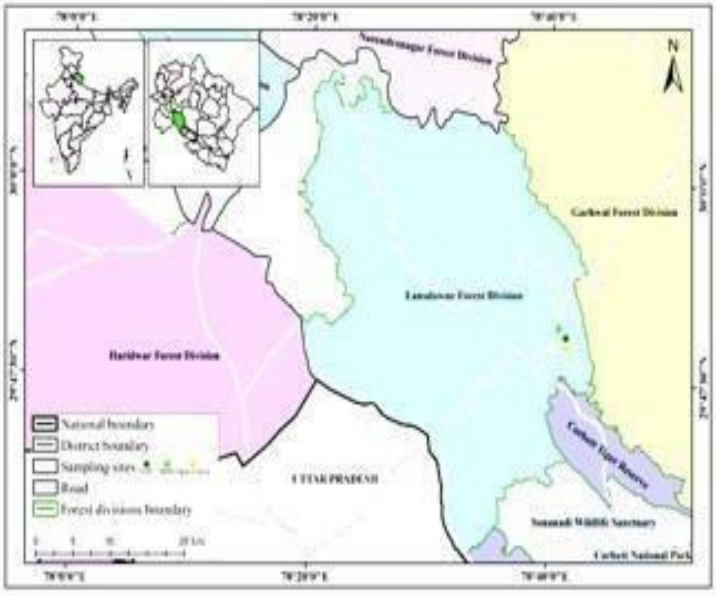

Fig. 1(d) Area map of Lansdowne

Analysis of soil samples Soil carbon stock

The soil sample were collected analysed in laboratory and the soil organic carbon was estimated by standard Walkley and Black (1934 and 1947). Amount of coarse fragments were estimated in each sample collected from different sites and deducted from the soil weight to get an accurate soil weight on hectare basis. Bulk density is a important soil parameter and is necessary to convert organic carbon content per unit area.

The SOC pool was calculated using the equation suggested by Inter governmental Panel on Climate Change (IPCC). The data for SOC pool was calculated by using the following equation as suggested by IPCC Good Practice Guidance for LULUCF: (IPCC ,2003).

Horizon =n *Horizon =n*

SOC = Σ $SOC_{horizon}$ = Σ ([SOC] * Bulk 1density * depth * (1 – C fragments) * 10) horizon

Horizon=1 *Horizon*= 1 Where,

SOC = Representative soil organic carbon content for the forest type and soil of interest, tones C $ha.^{-1}$

$SOC_{horizon}$ = Soil organic carbon content for a constituent soil horizon, tones C ha^{-1}

[SOC] = Concentration of SOC in a given soil mass obtained from analysis, g C $(kg\ soil)^{-1}$

Bulk density = Soil mass per sample volume, tones soil m^{-3} (equivalent to Mg m^{-3})

Depth = Horizon depth or thickness of soil layer, m

C Fragment =% volume of coarse fragments / 100, dimensionless

RESULT AND DISCUSSION

After completion of the soil analysis, field and laboratory data was compiled and grouped for different density classes of oak forest covers to assess the reason for forest decrease nutrient status within their density classes of same forest. As the thickness of epi-edon and depth of soil varied from place to place, status of some soil properties like pH, organic carbon, available nitrogen, available phosphorus and potassium were classified into three group ie, high, medium and low as per standard range.

Table-1: Range of low, medium and high of soil parameters

Parameter	**Low**	**Medium**	**High**
Organic carbon (%)	<0.5	0.52-0.75	>0.75
Available N(%)	<0.0125	0.0125-0.025	>0.025
Available P(%)	<0.00045	0.00045-0.0011	>0.0011
Available K(%)	<0.0049	0.0049-0.0125	>0.0125

Table 2: Correlations in monsoon season

Correlations in monsoon season									
	pH	OC%	N%	P%	K%	SOC stock (tons ha^{-1})	SoilRespiration ($\mu CO_2 m^{-2} sec^{-1}$	Bactria colonies (per plate)	MBC (µg/g)
OC%	-0.74366								
N%	-0.63768	0.770808							
P%	-0.44124	0.515759	0.446744						

K%	-0.76498	0.814794	0.864182	0.381561					
Soc stock(tons ha^{-1})	-0.73252	0.722428	0.718151	0.485457	0.727026				
SoilRespiration ($\mu CO_2 m^{-2} sec^{-1}$	-0.74152	0.772311	0.773244	0.542371	0.705619	0.754825			
Bactria colonies(per plate	-0.72287	0.760431	0.822423	0.530255	0.784442	0.665967	0.927604	1	
MBC (µg/g)	-0.59281	0.688543	0.545713	0.33113	0.565921	0.564265	0.663619	0.678765	
Bulk Density(gm/cm^3)	0.412257	-0.55857	-0.51893	0.013052	-0.57891	-0.33594	-0.44747	-0.47495	-0.46372
**. Correlation is significant at the 0.01 level (2-tailed).									
*. Correlation is significant at the 0.05 level (2-tailed).									

The correlation coefficient between different soils in monsoon season properties are presented in table 2. The pH was significant negatively correlated with organic carbon, negative correlation with N. the N was significant positively correlated with organic carbon content. Soil phosphorus was also negatively correlated with pH but positively correlated with organic carbon and nitrogen. Soil potassium significant negatively correlated with pH and significant positively correlated with organic carbon and nitrogen, however weakly positive correlated with phosphorus. Carbon stock was negatively correlated with pH but positively correlated with OC, N, P and K. Soil respiration was negatively correlated with pH and positively correlated with OC, N,P,K and carbon stock. Bacteria Colonies was negatively correlated with pH but strongly positive correlated with soil respiration and N, however, moderately positive correlation with O.C, P, K and carbon stock. MBC was also negatively correlated with pH but positively correlated with OC, N, P, K, carbon stock and Bacteria Colonies. Bulk denisty was positively correlated with pH and P but negatively correlated with OC, N, K, carbon stock, soil respiration and Bacteria Colonies.

Table 3: Correlations in winter season

correlation table in winter season									
	pH	OC%	N%	P%	K%	SOC stock (tons ha-1)	SoilRespiration (µCO2m-2sec-1	Bactria colonies(per plate)	MBC (µg/g)
OC%	-0.71387								
N%	-0.77326	0.773177							
P%	-0.14018	0.026739	0.138789						
K%	-0.73622	0.852473	0.846522	0.077623					
Soc stock(tons ha-1)	-0.78621	0.80948	0.803925	0.035015	0.827594				
Soil Respiration ($\mu CO_2m^{-2}sec^{-1}$	-0.69392	0.72479	0.727361	0.089827	0.85477	0.690769			
Bactria colonies(per plate	-0.80732	0.816803	0.774679	0.148723	0.863083	0.862652	0.893184		
MBC(µg/g)	-0.66696	0.723006	0.732456	-0.0151	0.729532	0.856585	0.739484	0.839973	
Bulk Density(gm/cm^3)	0.451217	-0.68503	-0.49074	-0.18207	-0.63094	-0.61152	-0.64695	-0.75442	-0.65169
**. Correlation is significant at the 0.01 level (2-tailed)									
*. Correlation is significant at the 0.05 level (2-tailed)									

The correlation coefficient between different soils in winter season properties are presented in table 3. The pH was significant negatively correlated with organic carbon, negative correlation with N. the N was significant positively correlated with organic carbon content. Soil phosphorus was also negatively correlated with pH but positively correlated with organic carbon and nitrogen. Soil potassium significant negatively correlated with pH and significant positively correlated with organic carbon and nitrogen and phosphorus. Carbon stock was negatively correlated with pH but positively correlated with OC%, N%, K% and weekly correlated with P. Soil respiration was negatively correlated with pH and positively correlated with OC%,N%,P%,K and carbon stock.

Bacteria Colonies was negatively correlated with pH but strongly positive correlated with soil respiration and N%, O.C%, K%, carbon stock but weekly correlated with P. MBC was also negatively correlated with pH and P% but positively correlated with OC%, N%, P%, K%, carbon stock and Bacteria Colonies. Bulk denisty was positively correlated with pH, P% and Bacteria colonies but negatively correlated with OC%, N%, K%, carbon stock, soil respiration. In summer season P% shown negative correlation with other properties of soil but shows positive correlation with due pH and bulk density.

Table 4: Correlation Table Summer Season

Correlation Table Summer Season									
	pH	OC%	N%	P%	K%	SOC stock (tons ha-1)	SoilRespiration (µCO2m-2sec-1	Bactria colonies (per plate)	MBC (µg/g)
OC%	-0.79941								
N_%	-0.70321	0.741574							
P_%	-0.05574	0.094523	0.09762						
K_%	-0.6674	0.816858	0.809558	0.157203					
SOC stock (tons ha-1)	-0.78129	0.730913	0.710851	0.149027	0.781421				
SoilRespiration (µCO2m-2sec-1	-0.81736	0.854874	0.806883	0.153942	0.888156	0.821653			
Bactria colonies(per plate)	-0.71208	0.666772	0.645555	0.167511	0.770478	0.704004	0.851589		
MBC (µg/g)	-0.60654	0.502911	0.470488	-0.08221	0.595236	0.579354	0.665659	0.572534	
BD(gm/cm^3)	0.048145	-0.26436	-0.02725	0.090871	-0.09659	-0.15323	-0.12248	0.180533	-0.10259
**. Correlation is significant at the 0.01 level (2-tailed).									
*. Correlation is significant at the 0.05 level (2 -tailed).									

The correlation coefficient between different soils in summer season properties are presented in table 4. The pH was significant negatively correlated with organic carbon, negative correlation with N. the N was significant positively correlated with organic carbon content. Soil phosphorus was also negatively correlated with pH but

positively correlated with organic carbon and nitrogen. Soil potassium significant negatively correlated with pH and significant positively correlated with organic carbon and nitrogen, however weakly positive correlated with phosphorus. Carbon stock was negatively correlated with pH but positively correlated with OC%, N%, P% and K%. Soil respiration was negatively correlated with pH and positively correlated with OC%, N%, P%, K% and carbon stock weekly correlated with P%. Bacteria Colonies was negatively correlated with pH but strongly positive correlated with soil respiration and OC%, N%, K5, carbon stock weekly correlated with P%. MBC was also negatively correlated with pH and P% but positively correlated with OC%, N%, P%, K%, carbon stock and Bacteria Colonies. Bulk density was positively correlated with pH, P and Bacteria colonies but negatively correlated with OC%, N%, K%, carbon stock, soil respiration.

DISCUSSION

Soil properties under different season classes of oak forest under depth 0-30 cm were estimated. The was under oak forest ph was acidic but their acidicity was increased with decreased density classes. this might be due to higher decomposition of organic matter release of organic acids during this process. the soil of dense forest content higher amount of organic matter. As followed by moderate an open oak forest. Among all the nutrients such as available Nitrogen, Phosphorus and exchangeable Potassium were higher in dense forest decreased with density wise. The other properties was also increased with density classes. SOC stock increased with density wise, Similar trends was observed increased by Raina and Gupta (2013). The similar trends was found chemical properties of soils in relation to forest composition in moist temperate valley slopes of Garhwal Himalaya, India, Gairola *et al* (2012). N showed a positive relationship with C and K. P was positively correlated with C and negatively correlated with soil ph value and density classes' wise density classes of all oak forest types. K was found to be positively correlated with C and N. pH of all the dense forest types was slightly acidic. C was comparatively higher dense forest as followed by moderate and open oak forest. In soil carbon stock was higher dense Oak forest as followed by moderate and open forest. Micro- organism (bacterial colonies was also, higher in dense forest as followed by moderate and open forest. Soil respiration also positive correlation with O.C%, N%, P%, K%, MBC, Carbon stock and Bacterial colonies. The pH of all the soil samples was acidic in nature. The availability of nutrients for plant is highly influenced by soil pH and it indicates the soil fertility (Zhao et al. 2012).

Observed, which may be due to different density classes having different composition of forest types along the altitudinal gradient and their differential decomposition rates. C content decreased with the different density of the soil. C showed positive correlation with N%, P%, and K%. N% showed a positive correlation with O.C%. pH showed a negative correlation with OC% and N%, K%. P% showed no relationship with the phytosociological parameters.

This study also provides the comparisons between the results of chemical analysis of the present study with numerous other previous studies in the temperate Himalayan region of the Uttarakhand. The SOC varies with land use types (Gupta et al., 2015) **Conclusion**

The observation has been seen that co-relation between soil physico-chemical and biological properties of soil under dense forest was higher as followed by moderate and open oak forest in all three selected district Dehra dun, Pauri Garhwal and Tehri Garhwal of Uttarakhand .(dense, moderate and open forest).The dense forest soil was highly porous and high amount of moisture contained, higher litter fall under dense forest which provide to condition to microorganism to increasing the decomposition rate of soil. The microorganism release large amount

of organic acid through respiration which increase the fertility of soil but beside this the density of forest classes decrease the decomposition rate slow the respiration was decreased the and fertility of soil also decreased.

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