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IMPACT OF ALTITUDES ON SOIL CHARACTERISTICS AND ENZYMATIC ACTIVITIES IN FOREST AND FALLOW LANDS OF ALMORA DISTRICT OF CENTRAL HIMALAYA

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Abstract: Altitude is one of the major topographical factors which influence the fertility status of soil. Population explosion has rooted deforestation at different altitudes to bring more area under cultivation leading to fallow lands. Objective of this study was to assess the impact of altitude on electro-chemical properties and enzymatic activities of forest and fallow land soils of Almora district of Central Himalaya. Seventy soil samples were collected from different altitudes of forest and fallow lands of Almora. Electro-chemical properties, soil microbial biomass carbon (SMBC), β-glucosidase, dehydrogenase and phosphatase activities were determined following the standard procedures. Both forest and fallow land soils were acidic in nature. Content of organic carbon, nitrogen, phosphorous and potassium were high in range and increased with altitudes. Average content of total nitrogen, phosphorous and potassium in forest lands was 2115.39, 111.89 and 2189.36 kg ha^{-1}, respectively. Similarly for the fallow lands the corresponding values were 1491.27, 80.26 and 2650.75 kg ha^{-1}, respectively. SMBC of forest soil was positively and significantly correlated with β-glucosidase, dehydrogenase and phosphatase activities but in fallow land soil, it was significantly correlated only with dehydrogenase activities (r=0.69). All enzymes of forest soil were positively and significantly correlated with organic carbon, total nitrogen and total potassium. For fallow lands dehydrogenase activity was positively and significantly correlated with nitrogen (r=0.65) and potassium (r=0.76) while phosphatase activity was negatively and significantly correlated with total phosphorous (r= -0.71). Concluded that altitude directly or indirectly has influenced fertility status, SMBC and enzymatic activities of forest as well fallow land soils.

Keywords: Altitude; β-Glucosidase; Dehydrogenase; Macronutrients; Phosphatase; SMBC.

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INTRODUCTION

Soil is a complex system where in living soil organisms belonging to different taxonomic groups interact at different levels within the community and plays a significant role in maintenance of soil properties (Garbeva et al., 2004; Van et al., 2002). Soil microorganisms constitute a source and sink for nutrients and are involved in decomposition of wood, litter and organic matter, generating organic C, N and energy from these organic substrates (Ganjegunte et al., 2004; Lindahl et al., 2007). Forest soils are enriched with enormous nutrients due to the decomposition processes of the plants litter. So the soils in Himalayan region are very well suited for the high productivity and sustainability. But due to increased anthropogenic activities like rapid urbanization and infrastructure development in the naturally delicate ecosystem with unstable geology, steep slopes and heavy rains had hastened the degradation process of fertile soil in the Himalayan region. Many studies confined to agricultural soils have been performed to determine the ecological and environmental factors regulating microbial community structure (Baek and Kim, 2009; Grayston et al., 2001; Hogberg et al., 2007). However, in forest ecosystem and fallow lands such studies are rather limited. The main leader in the organic matter decomposition are the soil enzymes (Ajwa et al., 1999) whose activity is governed by the organic matter content of the soil (Klose and Tabatabai, 2000). Studies on soil enzyme activities will endow lot of information on the biochemical processes occurring in soil. It is alleged that soil biological parameters may be potential indicators of soil ecological stress (Kızılkaya and Bayrakli, 2005). Human activities that minimize the organic matter content of the soil may reduce enzyme activities and could alter the availability of nutrients for plant uptake (Dick et al., 1988). In these viewpoints, Himalayan Mountain in India is one of the highly influenced areas in the world due to the human activities (Nautiyal and Kaechele, 2007). Therefore, the study of microbial activity is important for understanding early changes in biological quality of soil following changes in the land management. Therefore, it is thought that assessment of electro-chemical properties and extracellular enzymatic activities of soil of forest and fallow lands at different altitudes is very significant to evaluate the altitudinal effect on the enzymatic activity and soil characteristics.

EXPERIMENTAL

Site description: The study site Almora, a district of Uttarakhand is a picturesque site located in the lap of Himalaya. The altitude of the study site varies from 3000 to 8450 feet above sea level with a dry period normally spanning from March to June, a rainy season from July to September and a winter season from October to February. The average temperature is 24 ^{0}C, varying with the altitude, and the natural vegetation is largely sal (*Shorea robusta* Gaertn.), pine (*Pinus roxburghii* Sarg.), mixed oak (*Quercus leucotrichophora* A. Camus), broadleaved oak and deodar (*Cedrus deodara* Loud.). The area is well populated having a population of 6,30,446 with agriculture as major activity dispersed along the slope. The soils belong to Inceptisols, Entisols, Mollisols and Alfisols in different regions.

Soil sampling: A total of seventy soil samples were collected from both forest and fallow lands from sites around Almora, Uttarakhand, India (Figure 1). The samples were collected by following the standard soil sampling procedure and then transported to the laboratory at Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi in isothermic bags. Soil samples were divided in two parts. One part of the samples were air dried and processed for electro-chemical analysis and another part of the soil samples were stored at 4^{o}C for biological and enzymatic analyses.

Electro-chemical analyses: Soil samples were analyzed for pH in a soil solution of ratio 1:2.5 wt:vol, with a glass electrode (Jackson, 1958); oxidizable SOC (Walkley and Black, 1934); total N, P and K were analyzed by digestion method as described by (Jackson, 1970).

Enzymatic assay: Soil enzymatic activities were carried out within a week of soil sampling. Dehydrogenase, β-glucosidase and phosphatase activities were assessed in soil samples of both type of lands using standard procedures as described by Casida et al. 1964, Hayano 1973 and Tabatabai and Bremner 1969, respectively.

Statistical analysis: Values of a particular characteristic of soil obtained from analysis of soil samples of different locations at same altitudes were pooled together. Data were analyzed statistically to draw conclusion of significance by using the method as described by Panse and Sukhatme 1961. The test of significance was carried out at 5 % level of significance by referring to 'F' table values.

Figure 1. Soil sampling sites

RESULTS AND DISCUSSION

Soil electro-chemical properties: Soil samples of both forest and fallow lands of Almora district are acidic in nature (Table 1). The chemical properties of soils at different altitudes are presented in Table 1.

Table 1: Soil characteristics of forest and fallow lands of Almora district

Altitudes	Forest Soil					Fallow Soil				
			Macro Nutrients (kg/ha)					Macro Nutrients (kg/ha)		
	pH	OC	N	P	K	pH	OC	N	P	K
3000-3500	5.66	1.99	1760.24	102.40	1440.87	6.00	1.05	1011.32	61.61	1815.77
3500-4000	5.53	2.5	1690.62	96.62	2050.43	5.97	1.35	1410.41	83.25	2252.02
4000-4500	5.80	2.07	1850.91	98.87	1860.98	6.06	1.36	1329.92	73.33	2876.41
4500-5000	5.90	1.41	2170.16	116.32	2330.54	6.01	1.88	1340.67	67.58	3046.08
5000-5500	6.12	1.12	2076.72	112.65	2100.64	6.04	1.82	1166.15	75.06	2593.31
5500-6000	6.04	1.69	2520.23	121.89	2420.96	6.12	2.14	2011.37	102.42	3090.91
6000-6500	5.92	2.07	2483.61	119.74	2540.34	6.18	1.74	1840.21	96.55	2771.29
6500-7000	5.85	2.34	2370.64	126.65	2770.09	6.17	1.84	1820.11	82.26	2860.17
SEM±	**NS**	**0.092**	**8.533**	**4.018**	**9.580**	**NS**	**0.095**	**10.502**	**4.173**	**11.430**
CD(p=0.05)	**NS**	**0.198**	**18.260**	**8.599**	**20.502**	**NS**	**0.204**	**22.475**	**8.930**	**24.461**

Forest soils: Soils from the forest land at different altitudes showed a varying range of electro-chemical properties (Table 1). The soil of the forest land was found to be acidic in nature. Also the organic carbon content in the soil was too higher in medium to high range. The calculated value for the organic carbon ranged from 1.12 to 2.50 %. Total nitrogen, phosphorous and potassium were also high in range. Quantity of all the macronutrient elements were more at higher altitudes compared to altitude below 5500 feet of height. Maximum SMBC was recorded at 5500-6000 feet of altitude and was lowest at 3000-3500 feet of height (Figure. 2). The SMBC in the soil samples was significantly well correlated with organic carbon (r=0.86) as well as the enzyme under study (Table 2). SMBC varied from one altitude to other. SMBC increased significantly upto 4000-4500 feet of altitudes then decreased significantly at the 4500-5000 feet.

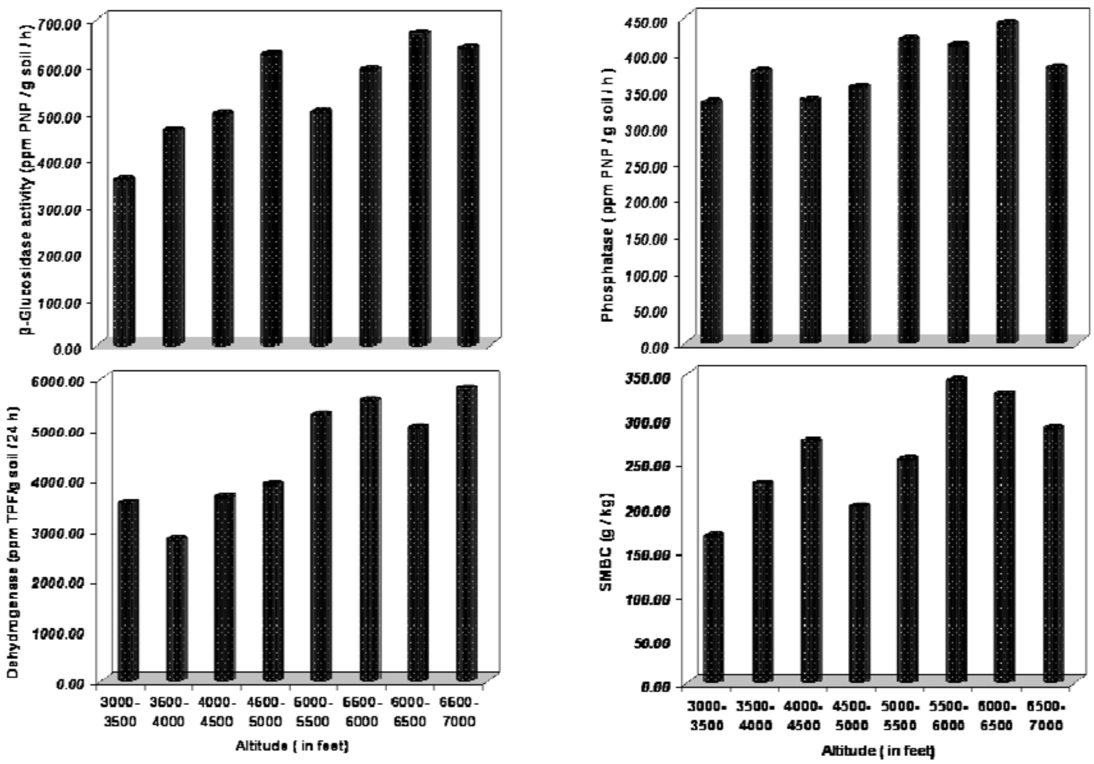

Figure 2. Soil Enzymatic Characteristics of Forest soil

Table 2: Simple correlation values of Forest soil

Variables	pH	Organic C	Total N	Total P	Total K	SMBC	β-Glucosidase	Dehydrogenase
pH	1.00							
Organic C	0.59	1.00						
Total Nitrogen	0.71*	0.74*	1.00					
Total Phosphorous	0.67*	0.67*	0.93**	1.00				
Total Potassium	0.49	0.83**	0.69*	0.75**	1.00			
SMBC	0.53	0.86**	0.77**	0.55	0.53	1.00		
β-Glucosidase	0.52	0.75**	0.86**	0.80**	0.85**	0.67*	1.00	
Dehydrogenase	0.80**	0.79**	0.86**	0.89**	0.68*	0.70*	0.63	1.00
Phosphatase	0.60*	0.72*	0.69*	0.56	0.64	0.71*	0.57	0.66*

The activity of dehydrogenase, β-glucosidase and phosphatase activity was recorded to be lowest at 3000-3500 altitude. Their activity increased as we move from one altitude to the other (Figure 2). This increase was statistically significant for all the enzymatic activities under the study. Activity of dehydrogenase was significantly correlated with organic carbon (r=0.79), total nitrogen (0.86), total phosphorous (0.89) and total potassium (0.68). Also it possesses positive significant correlation with phosphatase enzyme activity (r=0.66). The β-glucosidase enzyme had insignificant correlation with dehydrogenase and phosphatase activity. Over all altitudes had significantly influenced the all three enzymes under study and their activity was high at higher altitude.

Fallow Soil: Though the fallow land soil was acidic in nature but it was noticed to be less acidic as compared to forest soil. The pH of the fallow land ranged from 5.97 to 6.18 (Table 1). Also the altitude has insignificant effect on the pH of the fallow land. Organic carbon content in the soils of fallow land was high but lower than the forest soil. Altitudes significantly influenced the organic carbon content of fallow land (Table 1). Maximum content of organic carbon was recorded at 5500-6000 feet of height that was significantly superior to all other altitudes. Greater amount of organic carbon was observed at higher altitudes compared to lower altitudes. Content of macro nutrient recorded in soil were significantly influenced by the altitude (Table 1). Likewise the forest lands, in fallow lands maximum content of macronutrient were recorded at 5500-6000 feet of altitude. Overall the nutrient content in the soil was higher in range but were lower as compared to the forest land soils.

It was noted that SMBC was significantly influenced by the altitudes (Figure. 3). At all the altitudes significantly greater SMBC was recorded as compared to SMBC at 3500-4000 feet of altitude. Enzymatic activity was prominent in the fallow land soil (Fig. 3). In general, enzymatic activities studied in the area were influenced significantly by the altitude, with some exception. Phosphatase activity at 6000-6500 feet insignificantly differed from the activity at 5500-6000 feet of altitude. Similarly activity of β-glucosidase at altitude 4500-5000 and 5000-5500 differed significantly. In general the phosphatase and β-glucosidase were higher in forest land compared to fallow land soil. However, reverse is true in case of dehydrogenase activity.

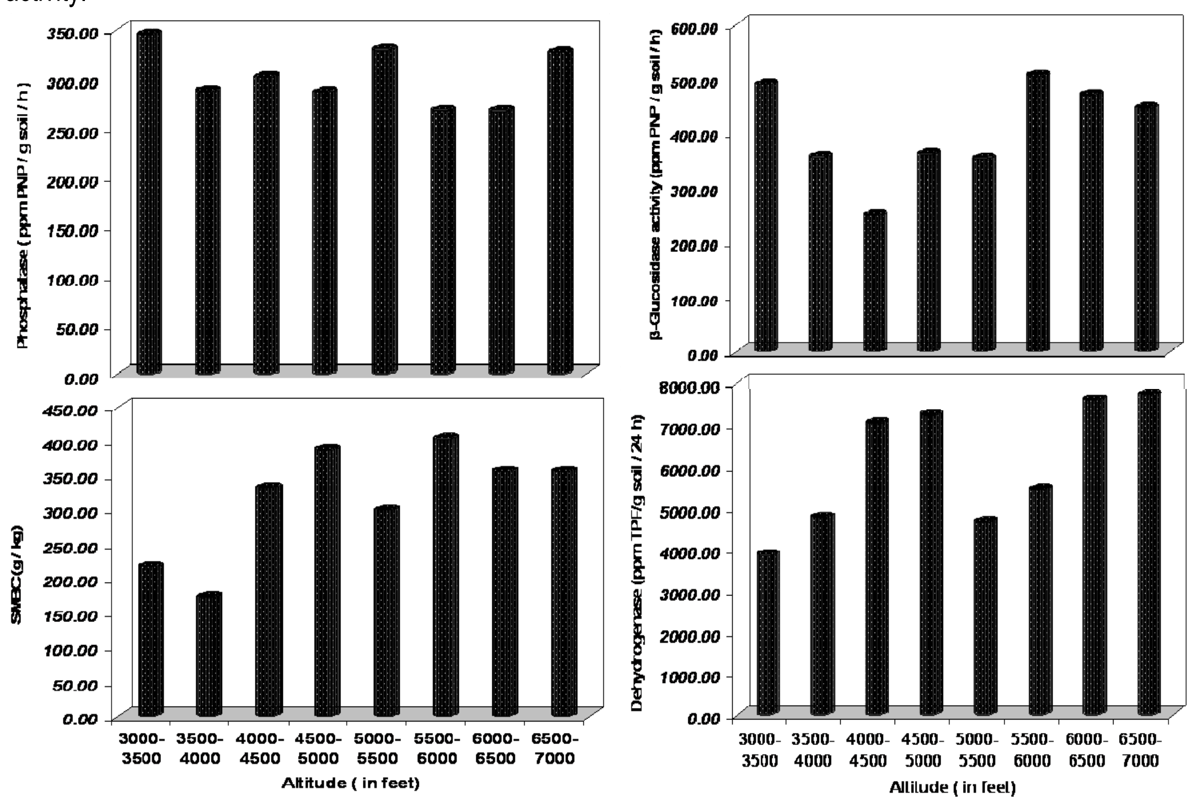

Figure 3. Soil enzymatic characteristics of fallow soil

Table 3 shows the simple correlation values generated amongst the parameters studied in fallow land soil samples. Statistical analysis of the data using ANOVA revealed that the dehydrogenase activity possess a significant positive correlations with total nitrogen (r=0.65), total potassium (r=0.76) and SMBC (r=0.69). Also dehydrogenase enzyme activities possess insignificant positive correlation with other soil fertility parameters. β-glucosidase failed to exhibit significant correlation with any of the parameters studied. Phosphatase activity exhibited a negative significant correlation with total phosphorous content in the fallow land soil.

Table 3: Simple correlation values of Fallow soil

	pH	Organic C	Total N	Total P	Total K	SMBC	β-Glucosidase	Dehydrogenase
pH	1.00							
Organic C	0.55	1.00						
Total Nitrogen	0.85**	0.63	1.00					
Total Phosphorous	0.67*	0.61	0.79**	1.00				
Total Potassium	0.54	0.81**	0.59	0.44	1.00			
SMBC	0.67*	0.80**	0.56	0.40	0.89**	1.00		
β-Glucosidase	0.44	0.24	0.41	0.41	-0.19	0.14	1.00	
Dehydrogenase	0.64	0.42	0.65*	0.25	0.76**	0.69*	-0.16	1.00
Phosphatase	-0.28	-0.47	-0.49	-0.71*	-0.56	-0.42	-0.05	-0.39

Altitude is one of the main factors which directly or indirectly affect the soil characteristics. The altitude determines the micro-climate of a site. The present study throws light on the variation in electrochemical and enzymatic activity in both forest soil and fallow soils of Almora, district of Himalaya. Soil supports the habitats which are important to biodiversity and it determines our scenic and recreational environment. The soil that develops in forest is somewhat different in nature than the soils developing in the fallow lands as former are more acidic as compared to the later. The same is attributed due to the decomposition of vegetation growing in the forest as well as the microbiological activities. It is evidenced by the work of Kumar et al. 2004 who had reported that soil in oak dominated and oak-pine mixed forest of Garhwal region in Himalaya is acidic in nature. The soil in order to nourish the trees has to be a mixture of air, water, decaying organic and inorganic materials and billions of living organisms within the surrounding ecosystem. The decaying organic matters with the help of both abiotic and biotic factors add nutrients to the soil. Houghton, 1999 has mentioned that land use changes in such as forest clearing, cultivation and pasture introduction as the main cause of change in soil chemical, physical and biological properties. But Celik, 2005 added that the sign and magnitude of these changes vary with land cover and land management. As a result of the decomposition of the vegetation and leaf litter soil of the Almora district of Himalaya is rich in carbon content. Content of nitrogen, phosphorous and potassium were high in range and well correlated with organic matter. It was Also noted that carbon and macronutrient content of the soil increased with altitudes. With rise in altitude, soil temperature decreases which in turn leads to a reduction in microbiological activity. Therefore, carbon has longer retention time in the soil and nitrogen levels are higher due to limited mineralization (Prichard et al., 2000). For the fallow lands the higher carbon and nutrient content were attributed to the decomposition of leaf and root litters of the vegetation. But the same were poor as compared to the forest land. Also fallow lands were once in use for agricultural practices and now left over due to some physical parameters like intruder animals and low nutrient condition in soil. So the carbon and other macronutrient content in these lands is less than the forest soil which is undisturbed. The higher concentrations of macronutrients (NPK) in forest sites than non-forest site also have been reported by Sheikh et al. 2009.

Soil microbial biomass in the forest and fallow lands exhibits relationship with the microflora of the soil. Over the last years, effect of agricultural management practices on soil properties and on crop yield has been widely studied in diverse type of agricultural soils (Liu et al., 2007; Mäder et al., 2002). In recent years, most of researchers have focused their study on microbial biomass and their activities which are confined to agricultural soils and in forest ecosystem such studies are rather limited. Soil microbial biomass carbon was recorded to be greater in the forest soil as compared to the fallow land soil. The high value in forest soil was attributed to the greater raw material in the form of organic nutrients in the forest due to higher plant cover. This fact is evident by the well correlation of SMBC with the organic carbon content of the forest soil (r=0.86). Witter and Kanal, 1998 had also reported a significant correlation for the SMBC with the organic matter. Along the altitudes the same trend of SMBC with organic carbon was also true. This indicates that the activities of the microbes vary from one altitude to the other in accordance to the organic matter content in the soil. It has been observed that the enzymatic activities varied significantly in accordance to the SMBC. Altitude significantly influenced the SMBC in both forest and fallow lands. A significant correlation of the SMBC with the enzyme β-glucosidase (r=0.85), dehydrogenase (r=0.68) and phosphatase (r=0.64) in forest soil indicate the greater availability of the organic material. In fallow land soil SMBC showed significant correlation with dehydrogenase (r=0.76). This might be due to lesser raw material for the enzyme. Ecosystems with high organic matter input and easily available organic matter compounds tend to have higher microbial biomass contents and activities because organic substances are preferred as a source of energy for the microorganisms (Hassink, 1994).

Soil microorganisms are the primary decomposer of wood, litter and organic matter, obtaining organic C, N and energy from these organic substrates (Heijden and Sanders, 2003; Lindahl et al., 2007). Enzymes, whether extracellular or intracellular, are essential for catalyzing reactions necessary for organic matter decomposition and their activities are strongly influenced by organic matter content of the soil. The dehydrogenase, β-glucosidase and phosphatase activities were dependent on the amount of organic carbon in soil as is evident from a significant correlation (r = 0.79), (r = 0.75) and (r = 0.72) respectively in forest soil. Besides organic carbon, soil nutrients are the most important factor likely to regulated by microbial activity. The enzymatic activities in the soil are influenced by the type and density of vegetational cover, climate and soil type as well as quality, quantity and distribution of litter. The observed variation in enzymatic activities might be due to their origins, tillage practices, different vegetation covers and spatial variability (Waldrop et al., 2000; Paudel and Sah, 2006). Dehydrogenase and Phosphatase originate from microorganisms and animals whereas β-glucosidase is produced by plants as well. Dehydrogenase and β-glucosidase activities were high in forest soil due to the greater availability of organic materials. In general, enzymatic activity studied in the area varied significantly with altitudes. One more possible influencing factor was anthropogenic activities like Lopping, logging, collection of firewood, fodder; litter etc. could influence the soil properties. Variations in anthropogenic activities at different altitude cause variation in the soil properties.

CONCLUSION

Soils of the Almora district are acidic in nature with abundance of macronutrients. Altitudes significantly influenced the microbial activity and the content of macro nutrients in soil. Organic carbon and nutrient content in soil increased with the altitude. Greater soil microbial activities were due to the high content of organic matter both in the forest and fallow land soils. As a result of vegetation succession in the fallow lands after abandonment of cultivation, organic matter, microbial biomass carbon, and other microbial activity gradually increased. An enzymatic activity which depends on the organic matter content in soil was well correlated with the organic carbon. Proper management of the fallow land could avert the conversion of the forest land to the culturable land. This will ecologically beautify the environment.

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CONFLICT OF INTEREST : Nothing