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Effect of forest fire on nitrogen mineralization in different land uses under Chir Pine (*Pinus roxburghii*) forest in North Western Himalayas

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Abstract
The purpose was aimed to evaluate the effect of forest fire on the nitrogen mineralization in different land uses based soil under Chir pine forest. Four different land uses *viz*. forest, grassland, agricultural and non fire site were selected for the study. For soil sampling PVC core sampling technique was adopted for obtaining reliable and precise results. Results of the study revealed that maximum mineralization rates were recorded during the rainy period in all land uses. With the passage of time the mineralization rates were again returned to pre fire levels. Mineralization rate were found to be increased with increase in temperature. Moreover, ammonification rates were favored more over nitrification in all land uses after inclusion of fire which could be a good alternate for nitrogen conservation for longer periods.

Keywords: Mineralization, nitrogen, forest ecosystem, nutrient management

Introduction
Forest fires have become a major serious problem since last decade in Himachal Pradesh and can be regarded as reason for extinction and migration of various forest species. Inclusion of fire lead to increase in soil temperature (>50 ºC) and ultimately such higher temperature kills the heat sensitive microflora. Further increase in soil temperature beyond 70 ºC directly extinguish the vegetation. Besides the negative effects forest fire is major contributor to nutrient recycling in soil. Burning of forest litter lead to oxidation of flora and fauna which results into inorganic N recharge in the soil (Diaz-Ravina *et al*., 1996) [7]. Various environmental factors i.e. amount, nature, and moisture of live and dead fuel, air temperature and humidity, wind speed, and topography of the site are responsible for magnitude of fire which alters the plant community succession, competition, eco physiology, soil nutrients and erosion (Brown and Smith, 2000) [3]. Heat caused by fire rapidly penetrate into the soil but latent heat of vaporization prevent such temperature from exceeding 95 ºC until the soil water completely vaporizes (Campbell *et al*., 1994) [4]. Sub surface soil mass is a pool of heavy fuels and burning of which cause increase in temperature of 500–700 ºC. The effects of fire on a forest landscape rely on the duration of fire (Shakesby and Doerr, 2006) [16]. For example, a low intensity fire resulted in reduced nutrient pools in forest floor: 54-75% of N, 37–50% of P, 43–66% of K, 31– 34% of Ca, 25–49% of Mg, 25–43% Mn, and 35–54% of B through the process of volatilization and oxidation (Raison *et al*., 1986) [15]. Fire is also responsible for chemical oxidation of organic matter and depends on fire duration and fire penetration capability in the soil (Hungerford *et al*., 1991) [10].

In Himachal Pradesh, practices of prescribed fires are very often in dry season and have been occurring since centauries. Moreover, prescribed burning of forest floor lowers the risk of wildfires. However, practice of forest litter burning have positive effect on reduced fuel levels, improving stand quality, nutrient concentrations in eco systems with the intention of minimizing the extent and severity of wildfires or facilitating germination and growth of desired forest species (Amo *et al*., 1995) [1]. Combustion of fire alters the transformation of nutrients and therefore affect their availability in the soil. However, organic matter combustion provides appreciable amounts of nutrients responsible for plant re-growth. The mineral ash also influence the soil pH and microbial activities related to decomposition and nutrient turnover (Deluca *et al*., 2002) [6]. The microbial biomass may be a main source of nutrient for plants and may contribute to nutrient conservation (Singh *et al*., 1989) [17]. Among the different nutrients, particularly nitrogen transformation is very dependent on fire as it causes a substantial loss of elemental N through volatilization. In many studies on fire effects on N transformation, net N mineralization as found to increased during the first months after the fire. Furthermore, forest fires were found to lower the nutrient pool of a site through some processes such as oxidation, volatilization, leaching, and erosion. Very limited research work has been done on the effect of fire on nitrogen mineralization in different land uses under pine ecosystem. So for a better understanding the present study effect of forest fires on nitrogen mineralization has been studied in the Chir pine (*Pinus roxburghii*) forest areas of Himachal Pradesh, India.

Material and methods

Study sites

The present study was conducted in Solan region, falls in sub-temperate climatic zone of Himachal Pradesh (Zone-2). During study period, the mean annual temperature of 17.4 ºC with annual rainfall of 1100 mm was recorded. Due to mountainous topography, climatic conditions in the district vary from place to place. Winter rains are meager in the region and being received during the months of January to March. Four land use sites located at 1275 amsl *viz*. forest area, grassland area, agricultural land area and non fire site taken as control were selected for the study.

For the sampling sites, plots of 200 m x 500 m were selected for each land uses. Non fire sites were selected separating fire areas with a distance of 2km. For soil samples, PVC core sampling method was used in which cores with 5 cm diameter and 10 cm long were inserted into the soil perforated with holes and capped on top. For the replication 10 cores were arranged in 3 parallel lines separating each other by 15 cm. Sampling were done on monthly basis from all the respective sites from soil surface depth (0-10 cm). Initial samples were drawn near the core and further samples were collected from the core with minimal disturbance. Mineralization rates were calculated for the monthly basis from all the respective land uses.

Results and Discussions

1. Soil characteristics

According to soil taxonomy USDA, the soils of the area were classified under Typic Eutrochrept at sub group level. The soil texture was sandy loam and sandy clay loam according to textural class in the different selected land uses (Table 1). Particle density of the soils varied between 2.32 to 2.35 g cm^{-3} while, bulk density were between 1.33 to 1.36 g cm^{-3}. Higher values of porosity could be due to presence of organic matter content and high amount of fine fractions present in soil which has a higher surface area Available soil nitrogen were in the range of 173.18 in forest land to 390.28 kg ha^{-1} in the agricultural land use. Whereas, soil available K content ranges from 272.68 in forest land to 431.88 in agricultural site (Table 1). However, the higher concentration of available potassium in the agricultural based ecosystems might be due to the reason that crops were given additional doses of inorganic fertilizers. Therefore, a good amount of potassium has been conserved in the soil through the crop residues in the agricultural fields. Uses of farm yard manure (FYM) along with inorganic sources might have also improved the potassium content in the soil.

Table 1: Soil initial physio-chemical properties under selected land use patterns

Initial physical and chemical properties								
Land use	**Particle density (g cm^{-3})**	**Bulk density (g cm^{-3})**	**Porosity (%)**	**pH (1:2)**	**Electrical conductivity (ds m^{-1})**	**Organic carbon (%)**	**Available N (kg ha^{-1})**	**Available K (kg ha^{-1})**
Forest land	2.32	1.33	42.70	5.93	0.22	1.18	173.18	272.68
Grass land	2.33	1.34	42.48	6.05	0.24	1.31	179.54	319.54
Agricultural land	2.35	1.36	42.12	6.44	0.27	1.22	390.28	431.88
Control (Non fire site)	2.32	1.33	42.67	6.57	0.25	1.17	291.29	339.52

2. N Mineralization

Net N-mineralization showed significant variations in all the selected land use systems. The greater amount of N-mineralization was recorded during the month march which received high amount of rainfall during both the years (Table 2). Whereas, the months received minimum rainfall least net N-mineralization has been observed. Pooling of two fire seasons data reported that in forest land, greater amount of net N mineralization (13.48 µg g^{-1} $month^{-1}$) was achieved in the month of August, while the month of October was also in same tune. Whereas, month of December had shown lowest N mineralization (5.02 µg g^{-1} $month^{-1}$) rate. In grassland area, month of September significantly improved the N mineralization rate by (9.69 µg g^{-1} $month^{-1}$) over the other months. Whereas, the least (0.96 µg g^{-1} $month^{-1}$) was observed in the month of April. In the agriultural based land use, higher rates on N mineralization (8.85 µg g^{-1} $month^{-1}$) was observed in the month of January. Whereas, least (0.23 µg g^{-1} $month^{-1}$) were recorded in the month of April. In non fire site, month of June improved the N- mineralization rate by (5.88 µg g^{-1} $month^{-1}$) over the other months. While the least rate (0.47 µg g^{-1} $month^{-1}$) was recorded in the months of April. Mineralization rate were found to be increased with increase in temperature. Higher mineralization rates were recorded during the rainy period. Similar findings supporting the result (Katterer *et al*. 1998; Numan *et al*. 2000; Bhuyan *et al*. 2014; Cassman and Munns 1980; Eghball 2000; DeLuca *et al*. 2002) [11, 14, 2, 5, 8, 6].

Table 2: Effect of forest fires on monthly variations in the soil N-mineralization (µg g^{-1} $month^{-1}$) in different land uses.

Month	**Year**	**Forest land**			**Grass land**			**Agricultural land**			**Control (Non fire)**		
		1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
June	2018	6.22	1.31	7.53	5.14	1.03	6.17	5.44	2.07	7.51	4.21	1.56	5.77
	2019	6.31	1.54	7.85	5.08	1.13	6.21	5.57	2.11	7.68	4.37	1.62	5.99
	Pooled	6.26	1.43	7.69	5.11	1.08	6.19	5.51	2.09	7.60	4.29	1.59	5.88
July	2018	6.27	1.39	7.66	5.42	1.14	6.56	1.04	2.98	4.02	0.88	2.09	2.97
	2019	6.35	1.71	8.06	5.37	1.29	6.66	2.26	2.27	4.53	1.94	1.99	3.93
	Pooled	6.31	1.55	7.86	5.40	1.22	6.61	1.65	2.63	4.28	1.41	2.04	3.45
August	2018	11.2	0.54	11.83	7.32	0.27	7.59	5.57	-0.12	5.45	4.79	-0.38	4.41
	2019	14.4	0.66	15.13	8.2	0.91	9.11	4.87	1.04	5.91	3.89	1.26	5.15

	Pooled	12.8	0.60	13.48	7.76	0.59	8.35	5.22	0.46	5.68	4.34	0.44	4.78
September	2018	5.88	1.67	7.55	7.44	1.16	8.60	6.32	-1.54	4.78	3.82	0.61	4.43
	2019	6.13	1.59	7.72	9.66	1.12	10.7	6.90	-0.33	6.57	4.87	-2.42	2.45
	Pooled	6.01	1.63	7.64	8.55	1.14	9.69	6.61	-0.94	5.68	4.35	-0.91	4.78
October	2018	9.94	1.84	11.78	6.98	0.67	7.65	3.19	1.71	4.90	2.68	0.98	3.66
	2019	8.65	1.83	10.48	7.84	1.76	9.60	4.18	1.74	5.92	3.65	2.61	6.26
	Pooled	9.30	1.84	11.13	7.41	1.22	8.63	3.69	1.73	5.41	3.17	1.80	4.96
November	2018	7.26	1.58	8.84	7.04	0.44	7.48	3.88	0.67	4.55	3.17	0.42	3.59
	2019	7.97	1.34	9.31	6.98	1.20	8.18	3.99	1.46	5.45	4.82	0.67	5.49
	Pooled	7.62	1.46	9.08	7.01	0.82	7.83	3.94	1.07	5.01	3.99	0.55	4.54
December	2018	4.02	1.14	5.16	3.22	0.55	3.77	3.43	1.02	4.45	2.91	1.16	4.07
	2019	3.84	1.04	4.88	4.23	1.01	5.24	4.48	1.05	5.53	2.14	1.44	3.58
	Pooled	3.93	1.09	5.02	3.73	0.78	4.51	3.96	1.04	4.99	2.53	1.30	3.83
January	2018	9.57	2.28	11.85	7.18	0.79	7.97	6.82	2.19	9.01	5.88	1.51	7.39
	2019	8.61	2.27	10.88	6.21	1.14	7.35	6.23	2.46	8.69	2.79	1.48	4.27
	Pooled	9.09	2.28	11.37	6.70	0.97	7.66	6.53	2.33	8.85	4.34	1.50	5.83
February	2018	4.09	1.91	6.00	3.91	0.41	4.32	4.04	1.89	5.93	3.08	1.07	4.15
	2019	5.95	1.74	7.69	4.95	1.23	6.18	3.94	1.97	5.91	-1.7	1.26	-0.44
	Pooled	5.02	1.83	6.85	4.43	0.82	5.25	3.99	1.93	5.92	0.69	1.17	1.86
March	2018	5.64	1.88	7.52	4.17	0.90	5.07	4.59	1.87	6.46	3.13	0.68	3.81
	2019	4.42	1.69	6.11	4.27	1.92	6.19	3.99	1.73	5.72	2.94	0.89	3.83
	Pooled	5.29	1.79	6.82	0.05	1.41	5.63	-1.12	1.80	6.09	-0.48	0.79	3.82
April	2018	5.21	1.24	6.45	2.09	0.63	2.72	-3.39	1.21	-2.1	0.64	0.81	1.45
	2019	5.37	1.28	6.65	-1.99	1.19	-0.8	1.14	1.49	2.63	-1.6	1.09	-0.51
	Pooled	5.29	1.26	6.55	0.05	0.91	0.96	-1.12	1.35	0.23	-0.48	0.95	0.47
May	2018	8.84	0.57	9.41	6.19	0.49	6.68	4.96	-0.42	4.54	2.41	-0.25	2.16
	2019	7.41	-0.64	6.77	5.40	0.52	5.92	3.41	-0.46	2.95	2.19	0.16	2.35
	Pooled	8.13	0.04	8.09	5.80	0.51	6.30	4.19	-0.44	3.75	2.30	-0.05	2.26
SE(±)	2018	(1= 0.41) (2 = 0.17) (3 = 0.43)											
	2019	(1 = 0.49) (2 = 0.18) (3 = 0.51)											
CD (0.05)	2018	(1 =1.20) (2 = 0.51) (3 = 1.25)											
	2019	(1 = 1.43) (2 = NS) (3 = 1.47)											

Where, 1-ammonification, 2-nitrification, 3- N-mineralization

Conclusions

Higher rates of N-mineralization were recorded during the rainy season in all the different land use patterns. Moreover soil temperature and moisture content were found to have a strong effect on mineralization process. Microbial activities favoring N mineralization are limited at soil temperature ranging to freeze but with rise in soil temperature mineralization rate increase and maximum N-mineralization achieved when soil temperature reaches 30-35 ^{0}C as these conditions are conducive for maximum microbial activities. Minimum mineralization rates recorded in winters could be due to low decomposition rates of litter because of lower microbial activities and greater immobilization of inorganic N resulting in reduced N-mineralization.

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