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EFFECT OF FOREST FIRE ON SOIL NUTRIENTS IN BLUE PINE (*PINUS WALLICHIANA* A.B. JACKSON) ECOSYSTEMS

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ABSTRACT

Forest fire is recognized as one of the major natural disaster, damaging huge forest and grassland areas worldwide. Fire can change plant composition, devastate biomass, alter soil physical and chemical properties and decrease nutrient pools. In recent years, Blue Pine *(Pinus wallichiana)* forests in South Kashmir are experiencing a heavy loss due to fire with respect to damage to undergrowth and disturbance in soil nutrient status. An assessment of damage in terms of ecological and economic attributes due to fire is deemed to be much. The frequency of fire is rising as biotic pressure on forest resources. This study demonstrates assessment of soil macro-nutrient alteration on sites on burnt with unburnt sites. The study sites are in South circle of Kashmir division in Jammu and Kashmir State of India. Our samples show 60% less soil carbon at 0-30 cm depth in burnt sites against their respective unburnt sites, Available soil nitrogen concentration was 35.28% lower on burnt sites, Available soil phosphorus was 38.89 % higher in burnt than unburnt sites and available soil potassium was 29.66 % higher on burnt sites in comparison to unburnt sites. Some implications of these results for forest managers are discussed. Organic carbon and nitrogen decreased in burnt areas while as potassium and phosphorus concentration witnesses an increase in burnt sites.

Key words : Fire, Soil nutrients, Blue pine, Organic carbon, Nitrogen, Phosphorus, Potassium.

Introduction

Forest fire being recognized as one of the major natural disaster, damages huge forest vegetation worldwide. The major change in the microclimate of the region in terms of soil moisture balance and increased evaporation is also attributed to the fire. Many believe that fires are bad but they are actually essential to promote diversity (Douglas *et al.,* 1971; Kovacic, 1998). Forest species alter in composition after fire, this may be good or bad depending on the utility of the stands that preceded and succeeded the fires (Lutz, 1956). According to Forest Survey of India report, about 6 per cent of forests are prone to severe fire damage. Estimated average tangible annual loss due to forest fire in our country is ` 440 crore (US $ 100 million approximately). Currently no data are available to calculate the effects of fire on forest ecosystem biomass and nutrient pools after fire, and as a result, the range of fire effects (positive or negative) on forests cannot be precisely explained or compared among fires or forest types.

Wildfires produce important changes in the physical, chemical, biological and biochemical properties of a soil. The effects of fire are particularly noticeable in the surface horizons, where erosion processes are favored and the nutrient biochemical cycles are altered due to structural changes, the loss of the organic matter and damaged biota. Although, in general, fire increases nutrient availability on the soil surface due to the combustion of organic forms and the addition of ashes from the burnt vegetation, the nutrient content of soil may decrease, remain unaffected or increase (Prieto-Fernandez *et al.*, 1993).

In view of the fact that the effect of fire are controlled by many factors explicit to individual fires, soils and forest types (species composition, age, stand structure, etc), it is not suitable to declare whether the effects of fire are beneficial or destructive to any given forest ecosystem. The role of fires in this area is important and inadequately understood, therefore, the objective of this study was to examine changes in some of the soil chemical properties following wildfire using existing field conditions and conservative soil investigative tools. Results from this study would provide insight into possible fire effects on nutrient pools and also give some valuable direction for badly needed future research.

Methodology

The study sites were located in the south circle in Kashmir division of India (N33^{0} 28' 12'' - 34^{0} 04' 3'' and E75^{0} 06' 47" - 75^{0}17'29''). The study sites are characterized by temperate to sub alpine climate. The altitude ranges from 2000 to 2850 m amsl. The analysis of

In burn site of *Pinus wallichiana,* loss of soil carbon and soil nitrogen was 60 and 35.28 per cent respectively, while soil phosphorus and soil potassium were 38.89 and 29.66 per cent higher.

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soil samples were conducted in laboratory of soil science division of Forest Research Institute, Dehradun, India. In this study, soil macro-nutrient changes were investigated on burnt and unburnt sites. The soil samples were collected in bags from three elevations at all the selected sites. The soil samples were collected from burnt and un-burnt plots from the depths of 0-15cm and 15-30 cm. The soils of two depths were mixed to make one representative sample. The fresh and oven dried weights of soil samples were recorded and the samples were used for soil analysis. Organic carbon was determined by wet digestion method of Walkey and Black (1954). Per cent organic carbon was estimated and analyzed. Available nitrogen was determined by alkaline permanganate method of Subbiah and Asija (1956). Available phosphorus was determined by Olsen *et al*. (1954). Exchangeable potassium was determined by method suggested by Blakemore *et al.* (1987).

Statistical analysis of collected data was conducted by factorial randomized block design having two factors as categories (burnt and un-burnt) and sites (10 sites) with 5 replications was used for analysis of collected data pertaining to soil properties using the SPSS software version 14.0. The main effects and interaction of the factors under the said design were checked at 5 % level of significance. Critical difference (CD) for main effects and interactions were calculated to compare the difference at the same level of significance.

Results and Discussion

Analysis of variance

Organic carbon (%) was significantly affected in both category and among different sites. But available nitrogen was significantly affected by category only. Available phosphorus on the other hand, was significantly affected in both category and among different sites. Similarly, exchangeable potassium was also significantly affected in both category and among different sites (Table 1).

Organic carbon (%)

A critical review of data in Table 2 indicates the main effect and interaction for the soil organic carbon of the factors category and sites under study area. The significant highest mean value (2.212 %) of soil organic carbon was observed at unburnt sites and the lowest mean value (1.533 %) was observed at burnt sites.

It was seen from the data in Table 1 that though non significant interaction between category and sites, the maximum numerical value of soil organic carbon (2.61 per cent) was observed at Site-2 x unburnt plot followed by Site-3 x unburnt plot (2.58 per cent), Site-1 x unburnt plot (2.33 per cent). The minimum value (1.25 per cent) was found at Site-10 x burnt plot.

The Figure 1 shows that the highest decrease (37.68 %) of soil organic carbon was recorded at burnt plot of Site-7 against its unburnt plot followed by Site-3 (36.43 %) and Site-1 (33.85 %) respectively, in decreasing order. Lowest decrease (23.03 %) was observed at Site-6. There is also significant difference between sites at same level of significance. It was also evident from data in Table 2 that the numerical maximum value of soil organic carbon (2.28 %) was recorded at Site-2 and minimum value (1.47) of organic carbon was observed at Site-10.

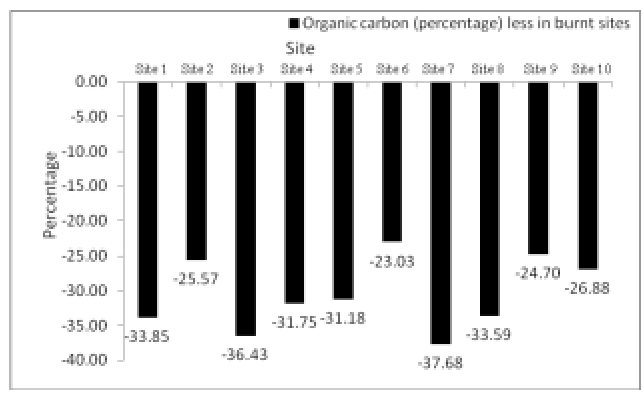

Fig. 1: Decrease (percentage) in Organic carbon at burnt sites against unburnt sites

In the present study, organic carbon percentage was higher on unburnt areas as compared to burnt areas in all the sites. Fires have relatively consistent effects on soil C and N at the global scale, even as site-to-site exceptions do occur. This is even the case for temperate forest floors, which we expected to have more dynamic responses to disturbance than mineral soils due to their exposed position at the top of the soil profile, which make them susceptible to direct combustion and post fire erosion, as well as their relatively small organic matter mass and sensitivity to litter and detritus inputs

Table 1 : ANOVA for different soil properties

Source of variation	*P* value			
	Organic Carbon (%)	Available nitrogen (kg ha^{-1})	Available Phosphorus (kg ha^{-1})	Exchangeable Potassium (kg ha^{-1})
Category	0.000	0.001	0.000	0.000
Sites	0.011	0.761	0.001	0.013
Replication	0.053	0.008	0.009	0.726
Category * Sites	0.951	0.999	0.781	1.000

Table 2: Organic carbon (%) of soils of selected sites.

Site	Category		
	Burnt	Unburnt	Mean ± SE
Site-1	1.54	2.33	$1.94^{a}\pm0.55$
Site-2	1.94	2.61	$2.28^{ab}\pm0.44$
Site-3	1.64	2.58	$2.11^{a}\pm0.56$
Site-4	1.49	2.19	$1.84^{a}\pm0.46$
Site-5	1.38	2.01	$1.69^{a}\pm0.62$
Site-6	1.52	1.98	$1.75^{a}\pm0.61$
Site-7	1.39	2.24	$1.82^{a}\pm0.68$
Site-8	1.53	2.30	$1.92^{a}\pm0.52$
Site-9	1.63	2.16	$1.89^{a}\pm0.59$
Site-10	1.25	1.70	$1.47^{ac}\pm0.52$
Mean ± SE	$1.53^{x}\pm0.46$	$2.21^{y}\pm0.46$	

Where a, b, c, x and y denote the means that share the same superscripts indicate similarity between those means.

(Robichaud and Waldrop, 1994; Binkley and Giardina, 1998; Currie, 1999). After 14 months the fire organic matter and nutrients in the burned soil were less than those of the unburned, except total P which significantly higher in the upper, burned, soil layer than in the unburned (Kutiel and Naveh, 1987).

Available nitrogen (kg ha^{-1})

The main effect and interaction for the available nitrogen (kg ha^{-1}) of the factors category and sites under study area is revealed by data in Table 3. The significant highest mean value (397.74 kg ha^{-1}) available nitrogen was observed at unburnt sites and the lowest mean value (362.52 kg ha^{-1}) was observed at burnt sites.

A scrutiny of the data in Table 3 reflects that the nonexistence of significant (5%) interaction between category and sites. However, the maximum numerical value of available nitrogen (417.64 kg ha^{-1}) was observed at Site-1 x unburnt plot, followed by Site-2 x unburnt plot (412.66 kg ha^{-1}) and Site-9 x unburnt plot (409.60 kg ha^{-1}) respectively in decreasing order. The minimum value (341.15 kg ha^{-1}) was observed at Site-10 x burnt plot.

It is apparent from the Figure 2 that the maximum decrease (13.60 %) of available nitrogen was observed at burnt plot of Site-1 against its unburnt plot followed by Site-2 (12.36 %) and Site-10 (10.56 %), while minimum decline (5.71%) was found at Site-7. There is no significant difference between sites at same level (5%) of significance. It is clear from the data in Table 4 that the numerical maximum value of available nitrogen (394.09 kg ha^{-1}) was recorded at Site-7 and minimum value (361.29 kg ha^{-1}) was observed at Site-10.

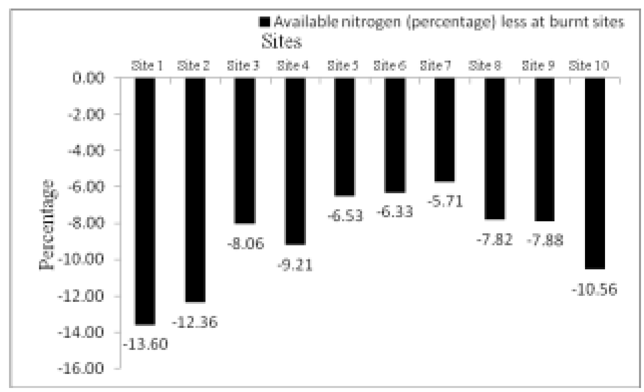

Fig. 2: Decrease (percentage) in available nitrogen at burnt sites against unburnt sites

The available nitrogen content in soil was recorded higher in unburnt sites in comparison to burnt sites. This

Table 3: Available nitrogen (kg ha^{-1}) of soils of selected sites.

Site	Burnt	Unburnt	Mean ±SE
Site-1	360.84	417.64	$389.24^{a}\pm42.32$
Site-2	361.63	412.66	$387.15^{a}\pm62.97$
Site-3	364.17	396.08	$380.12^{a}\pm56.48$
Site-4	365.96	403.07	$384.51^{a}\pm51.07$
Site-5	348.87	373.26	$361.07^{a}\pm64.19$
Site-6	353.90	377.81	$365.86^{a}\pm47.69$
Site-7	382.49	405.67	$394.09^{a}\pm50.85$
Site-8	368.88	400.16	$384.52^{a}\pm57.24$
Site-9	377.31	409.60	$393.46^{a}\pm60.83$
Site-10	341.15	381.43	$361.29^{a}\pm44.60$
Mean ± SE	$362.52^{x}\pm50.99$	$397.74^{y}\pm49.84$	

Where a, x and y denote the means that share the same superscripts indicate similarity between those means.

Table 4: Available phosphorus (kg ha^{-1}) of soils of selected sites.

Sites	Burnt	Unburnt	Mean ±SE
Site-1	31.050	24.444	27.747^{a}±4.163
Site-2	33.814	26.990	30.402^{a}±5.188
Site-3	36.072	28.860	32.466^{a}±6.056
Site-4	32.604	26.350	29.477^{a}±5.170
Site-5	34.310	27.734	31.022^{a}±4.101
Site-6	36.314	28.290	32.302^{a}±5.401
Site-7	36.020	29.904	32.962^{a}±4.606
Site-8	31.074	27.562	29.318^{a}±3.699
Site-9	33.880	23.736	28.808^{a}±6.096
Site-10	30.280	23.842	27.061^{a}±4.520
Mean ± SE	33.542^{x}±3.671	26.771^{y}±3.983	

Where a, x and y denote the means that share the same superscripts indicate similarity between those means.

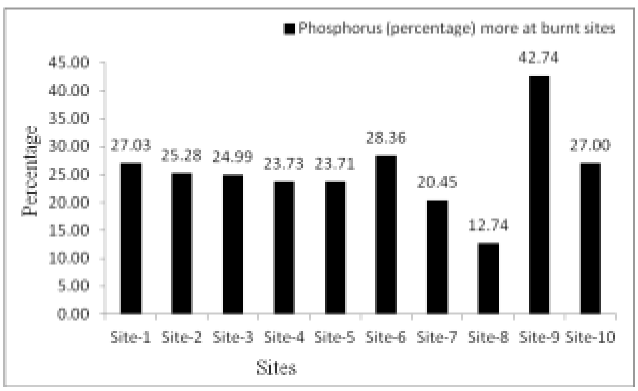

Fig. 3: Increase (percentage) in available phosphorus at burnt sites against unburnt sites

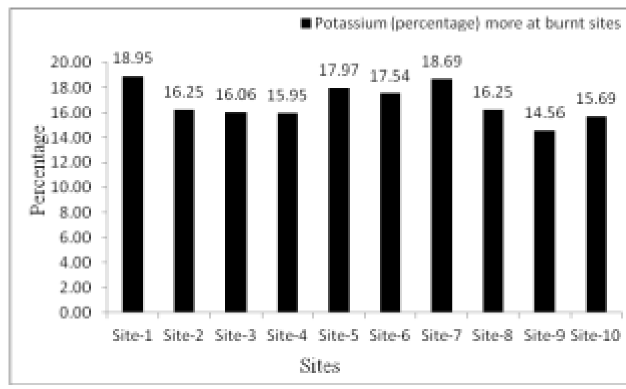

Fig. 4: Increase (percentage) in exchangeable potassium at burnt sites against unburnt sites

might be due to the effect of forest fire on soil microbes which are responsible for decomposition of organic matter of the soil layer which in turn neutralize the minerals in soils. Loss of nitrogen from top layer of soils might also be due to vaporization by forest fire. Nitrogen loss via volatilization occurs at temperatures <50^{0}C (De Bano *et al*., 1998). Neff *et al*. (2005) also reported similar results.

Available phosphorus (kgha^{-1})

The data in Table 4 showed the main effect and interaction for the available phosphorus of the factors category and sites under study area. The *p* value indicates that the main effect of category have significant difference at 5% level of significance. The significant highest mean value (33.54 kg ha^{-1}) of available phosphorus was observed at burnt sites and the lowest mean value (26.77 kg ha^{-1}) was observed at unburnt sites.

It was observed from the data in Table 4 that though non significant interaction between category and sites, the maximum numerical value of soil organic carbon (36.31 kg ha^{-1}) was observed at Site-6 x burnt plot followed by Site-3 x burnt plot (36.07 kg ha^{-1}), Site-7 x burnt plot (36.02 kg ha^{-1}). The minimum value (23.74 kg ha^{-1}) was found at Site-9 x unburnt plot.

Figure 3 showed highest increase (42.74 %) of available phosphorus between burnt and unburnt sites at burnt plot of Site-9 against its unburnt plot followed by Site-6 (28.36 %), Site-1 (27.03 %) and Site-10 (27.00 %). Minimum decrease (12.74 %) was observed at Site-8. Significant difference was observed between sites at same level of significance. However, the data in Table 6 reveals numerical maximum value of available phosphorus (32.96 kg ha^{-1}) was recorded at Site-7 and minimum value (27.75 kg ha^{-1}) of available phosphorus was observed at Site-1.

The available phosphorous content in soil was recorded higher in burnt sites and this increase may be due to addition of ash to soil and combustion of organic phosphorus. Kutiel and Shaviv (1992) reported that increase in available phosphorus is due to combustion of organic phosphorus and transformation of mineral phosphorus. Similar results were also reported by (Wable and Kitchen, 1972; Trabaud, 1980; Cade-Menun *et al*., 2000).

Exchangeable potassium (kg ha^{-1})

A critical review of data in Table 5 indicates the

Table 5: Exchangeable potassium (kg ha^{-1}) of soils of selected sites.

Site	Burnt	Unburnt	Mean ±SE
Site-1	271.14	227.95	249.55^{ab}±30.62
Site-2	258.08	221.99	240.04^{a}±28.34
Site-3	248.07	213.75	230.91^{a}±27.03
Site-4	244.57	210.93	227.75^{a}±22.39
Site-5	249.56	211.54	230.55^{a}±23.87
Site-6	257.55	219.11	238.33^{a}±30.24
Site-7	246.07	207.33	226.69^{a}±23.11
Site-8	230.32	198.12	214.22^{ac}±25.24
Site-9	259.72	226.70	243.21^{a}±20.76
Site-10	246.82	213.35	230.08^{a}±31.36
Mean ± SE	251.19^{x}±23.75	215.08^{y}±15.71	

Where a, b, c, x and y denote the means that share the same superscripts indicate similarity between those means.

main effect and interaction for the exchangeable potassium of the factors category and sites under study area. From the *p* value, significant difference at 5% level of significance was observed for the main effect of category. The significant highest mean value (251.19 kg ha^{-1}) of exchangeable potassium was observed at burnt sites and the lowest mean value (215.08 kg ha^{-1}) was observed at unburnt sites.

There is significant difference between sites at same level of significance. Data in Table 8 showed that the numerical maximum value of exchangeable potassium (249.54 kg ha^{-1}) was recorded at Site-1 and minimum value (214.22 kg ha^{-1}) was observed at Site-8.Table 8 shows the absence of interaction between category and sites, however, that highest numerical value of exchangeable potassium (271.14 kg ha^{-1}) was observed at Site-1 x burnt plot followed by Site-9 x burnt plot (259.72 kg ha^{-1}), Site-2 x burnt plot (258.08 kg ha^{-1}) and Site-6 x burnt plot (257.55 kg ha^{-1}) respectively in decreasing order. The lowest value (198.12 kg ha^{-1}) was observed at Site-8 x unburnt plot.

It is clear from the Figure 4 that the maximum increase (18.95 %) of exchangeable potassium was observed at burnt plot of Site-1 against its unburnt plot followed by Site-7 (18.69 %) and Site-5 (17.97 %), while minimum increase (14.56 %) was found at Site-9.

The available potassium content (%) in soil was recorded slightly higher in burnt areas on each site as compared to unburnt locations. This may be due to the ash deposition by fire that contains large amount of potassium. Numerous studies in different ecosystem have reported increase in exchangeable K, in post fire soil (Austin and Basinger, 1955; Hatch, 1960; Lewis, 1974; Marfa and Chau, 1999).

Conclusion

It may be concluded that fire results in losses of nutrients to the atmosphere via volatizations, fly-ash, and leaching through the soil, concentration of OC and N in burnt soils decreases. The available P and available K in burnt soils increases and these changes may have species specific benefits for some plants by increasing the short-term availability of nutrients for plant growth. Kashmir foresters are unwilling to use fire in forestlands; however, in some cases prescribed fires with lower severity and high frequency may act as a mineralizing agent in increasing the short-term availability of nutrients in regeneration sites.

ब्लू पाइन (*पाइनस वालिचियाना* ए.बी. जैकसन) पारितंत्रों में मृदा पोषकों पर वनाग्नि का प्रभाव

बिलाल. ए. खाकी, वी.आर.आर. सिंह, अखलाक ए. वानी और राज.के. ठाकुर

सारांश

वनाग्नि को प्रमुख प्राकृतिक आपदा में से एक के रूप में माना गया है, जो विश्व भर में विशाल वन और घास भूमि क्षेत्रों को नुकसान पहुंचाती है। आग पादप संयोजन में परिवर्तन, जैवमात्रा का विध्वंश, मृदा भौतिक एवं रासायनिक गुणों में परिवर्तन और पोषक पूलों को घटा सकती है। हाल के वर्षो में दक्षिण कश्मीर में ब्लू पाइन (*पाइनस वालिचियाना*) वन मृदा पोषक स्तर में विक्षोभ और अधोवृद्धि की क्षति के संबंध में आग के कारण भारी क्षति का सामना कर रहा है। आग के कारण पारिस्थितिकीय एवं आर्थिक लक्षणों के संदर्भ में क्षति का मूल्यांगन काफी अधिक है। वन संसाधनों पर जीवीय दबाव के रूप में आग की बारम्बारता बढ़ रही है। यह अध्ययन बिना जले स्थलों के साथ जले स्थलों पर मृदा वृहद–पोषक परिवर्तन के मूल्यांगन का प्रदर्शन करता है। अध्ययन स्थल भारत के जम्मू और कश्मीर राज्य में कश्मीर प्रभाग के दक्षिणी सर्किल में हैं। हमारे नमूने बिना जले स्थलों की तुलना में जले स्थलों में 0–30 से.मी. गहराई में 60% कम मृदा कार्बन दर्शाते हैं, उपलब्ध मृदा नाइट्रोजन सान्द्रता जले स्थलों में 35.28% निम्न थी, उपलब्ध मृदा फॉस्फोरस बिना जले स्थलों की अपेक्षा जले 38.89% उच्च थी और उपलब्ध मृदा पोटेशियम बिना जले स्थलों की तुलना में जले स्थलों में 29.66% उच्च थी। वन प्रबंधकों के लिए इन परिणामों की कुछ जटिलताओं पर चर्चा की गई है। आर्गेनिक कार्बन और नाइट्रोजन जले क्षेत्रों में घटी जबकि पोटेशियम और फॉस्फोरस सान्द्रता जले स्थलों में वृद्धि करते हुए देखी गयी।

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