

## Fluctuations in soil nutrients and physico-chemical properties following controlled fire in North-Western Himalayas

**Sakshi Vishvamitera** ✉

Department of Soil Science, Dr. YS Parmar University of Horticulture and Forestry, Solan, India.

**Uday Sharma**

Department of Soil Science, Dr. YS Parmar University of Horticulture and Forestry, Solan, India.

**Abhinav Guleria**

Department of Soil Science, Dr. YS Parmar University of Horticulture and Forestry, Solan, India.

ARTICLE INFO	ABSTRACT
<p>Received : 25 November 2021  Revised : 15 February 2022  Accepted : 21 February 2022</p> <p>Available online: 17 April 2022</p> <p><b>Key Words:</b>  Chir pine forest  Controlled fire  Grassland  Nitrogen  Phosphorus  Scrubland</p>	<p><b>Controlled fire effect on nutrients and physico-chemical properties of soil was investigated after a span of one year of controlled fire under four land uses viz. chir pine forest (<i>Pinus roxburghii</i>), grassland, scrubland and non-fire site in chir pine (control). In March 2018, a controlled fire was caused, and soil samples were taken after one year of burning at different soil depths (viz. 0-5 cm, 5-10 cm and 10-15 cm). The experiment consisted of five replications in factorial randomized block design. The results revealed that in comparison to pre-fire assessment, available nitrogen, phosphorus and potassium slightly increased, whereas, soil organic carbon decreased slightly in post-fire assessment. The soil pH, electrical conductivity, bulk density and soil texture did not show any significant change after one year of burning. The study concludes that controlled fire did not cause any drastic fluctuations in nutrients and physico-chemical properties of soil and can be used as an effective management practice for combating the negative effects of wildfire on soil.</b></p>

### Introduction

Fires in forests are a very prevalent hazard. During the summer, the woods are strewn with dry, senescent leaves and twigs that can catch fire and be ignited by the smallest spark. Due to the widespread expansion of chir forests in many parts of the Himalayas, the frequency and intensity of forest fires has also increased. They devastate not only the forest, but also the entire fauna and flora regime by drastically disrupting a region's biodiversity and ecosystem. Natural wildfires are uncommon in grasslands and scrublands, however, fires are intentionally induced in these landuses for habitat management of various species of grasses and shrubs (Hore and Uniyal, 2008). Over the past 15 years, the global annual area burnt has averaged  $348 \times 10^6$  ha i.e. 2% of global land area (Giglio *et al.*, 2013). By causing volatilization and ash transfer, fire removes organic debris and nutrients from a location (Raison *et al.*, 1986). Snyman

(2003) describes fire as an active agent capable of mobilizing soil nutrients and restoring fertility. However, especially in severe wildfires, nutrient loss by volatilization, leaching and erosion is a major source of soil degradation. In fact, it is regarded as a substantial disturbance in many ecosystems resulting in significant changes in characteristics of soil (Certini, 2005) and plant community (Granged *et al.*, 2011a). The alteration in the nature (Knicker, 2007) and amount of soil organic matter is one of the most typical impacts of fire (Terefe *et al.*, 2008). Many studies found a decline in soil organic carbon (C) following fire (Fernández *et al.*, 1997; Novara *et al.*, 2011), while others (Kavdir *et al.*, 2005) found no significant alteration in soil organic C compared to pre-fire level. Dooley and Treseder (2012) observed decline in microbial biomass by an average of 33.2% following wildfires in several field

studies. Viswanathan *et al.* (2006) reported an increase in CO and NO<sub>2</sub> concentration by an average of 250% and 100% respectively, following wildfire resulted in environment pollution. Highly intense fires resulted in increase in sand and silt percentage and bulk density, however, soil nutrients, C stocks, N stocks, soil microbial biomass were observed to decrease by Jhariya and Singh (2021) in Boramdeo wildlife sanctuary, Chhattisgarh, Kumar *et al.* (2013) in Garhwal Himalayas, India and Chandra and Bhardwaj (2015). The impact of fire is very variable in time and place owing to the large number of regulating factors. Intensity, severity and regimen of fire, type of plant community, distribution of fuel on the soil, type of ash produced, topography and aspect, soil properties, region's climate and meteorological conditions in the immediate period following fire are among these factors. According to Fernandes *et al.* (2013) controlled fire or prescribed burning is the deliberate use of fire having low intensity to accomplish a variety of objectives such as habitat management of various plant species, to reduce fuel load to prevent destructive wildfires, insect populations and invasive plants etc. under specific meteorological, fuel, and terrain circumstances. It is recognised as a management tool for minimising carbon emissions (Bennet *et al.*, 2014) and mitigating other harmful activities due to occurrence of wildfires. Major goal of controlled fires is to eliminate the fuel load which otherwise can cause a severe wildfire as well as preserving ecological processes and biodiversity (Santin and Doerr, 2016; Valkó *et al.*, 2016). We hypothesized that there would be short-term infinitesimal alteration in nutrients and physicochemical properties of soil following controlled fire and can be used as an effective management tool to put out wildfires.

### Material and Methods

The study was conducted at Solan district of Himachal Pradesh, India. The research sites consists of chir pine forest, grassland, scrubland and unburnt chir pine area in same burnt chir pine plantations (control) under the Department of Silviculture and Agroforestry, Dr. Y.S. Parmar University of Horticulture and Forestry. The region lies at 30°52' North latitude and 77°11' East longitude (1260 m above mean sea level). The

research site lies under the sub-temperate, sub-humid agro-climatic zone-II of Himachal Pradesh, with an annual precipitation of nearly 1115mm (approximately three-fourth of it is received during June to September. Winter rains are few and far between, falling mostly in January and February. May&June are the hottest and December&January are the coldest months. Soil texture of experimental site was worked out to be gravelly silty clay loam. Rao (1998) reported that the soil of study site is derived from inferakasol which consists of calcareous shales, carbonaceous shales and dolomitic limestone with bands of intermittent shales. The soils of the experimental sites lies in the order Inceptisol and sub group Eutrochrept according to Soil Taxonomy of USDA.

### Experimental Design

Four experimental sites representing three different ecosystems and a control of unburnt chir pine site were selected. Initial soil samples were taken in the month of March, 2018 at three soil depths (0-5 cm, 5-10 cm and 10-15 cm) from a square having plot size of 50m× 50m for each land use. There were five replications in factorial randomized block design and each sampling square was nearly 5m apart from neighbouring square. A controlled fire was caused using stacks of vegetation which are ignited across a tract on the top of slope and then, burnt downslope at low-intensity under the supervision of officials and fire-fighters of Himachal Pradesh Forest Department in all selected land uses in order to simulate natural wildfire.

### Sampling and Analysis

After one year of controlled fire, soil samples were collected in March, 2019 from the same place from where pre-fire samples were collected in order to avoid sampling error at sites. Soil samples were collected using 50 mm × 54 mm cylindrical steel cores from five different locations from each treatment plot (chir pine forest, grassland, scrubland and unburnt chir pine) at three different depths (0-5 cm, 5-10 cm and 10-15 cm soil depth). A total of 60 soil samples were collected for assessment of post-fire conditions of soil. The samples were then air-dried, crushed in a wooden pestle mortar and passed through 2-mm sieve and then used. For determination of organic C in soil, soil samples were passed through 0.5 mm sieve and then used. The soil samples were analysed for available nitrogen (N), phosphorus (P), potassium

(K), organic carbon (C), soil pH, electrical conductivity (EC), bulk density and soil texture. Available N was estimated with the help of method given by Subbiah and Asija (1956). Available P was extracted by sodium bicarbonate having pH 8.5 and further determined by method given by Olsen *et al.* (1954). Available K was extracted with the help of procedure given by Mervin and Peech (1951) and K content in the filtrate was determined on the flame photometer. Rapid titration method was used for the determination of soil organic C (Walkley and Black, 1934). The soil pH and EC were estimated as described by Jackson (1973). Core sampler method given by Black (1965) was used for the estimation of bulk density of the unprocessed soil samples.

### Statistical Analysis

Data on soil nutrients and physicochemical properties post-fire were analysed by two-way analysis of variance (ANOVA) as per the model suggested by Panse and Sukhatme (2000). The data recorded was analysed using MS-Excel, OPSTAT and SPSS 16.0 package software as per design of the experiment.

## Results and Discussion

### Fire effects on available N, P and K

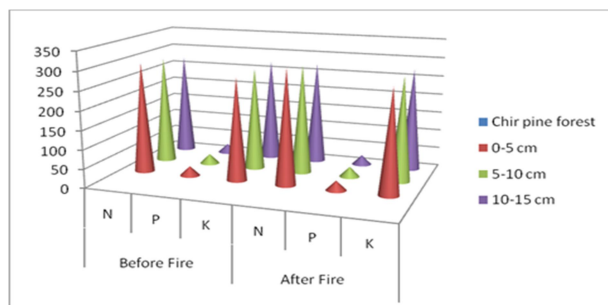
After twelve months of controlled fire, a slight increase in available nitrogen was observed under all the landuses compared to pre-fire level. At 0-5 cm depth, the highest % increase in available N was observed under burnt chir pine forest reaching upto 2.84 % (Figure 1) whereas, lowest was found under grassland soil (0.73 %) (Figure 2). At 5-10 cm and 10-15 cm soil depth, % increase in available N was found highest under scrubland (1.39 % and 3.17 %, respectively). On comparison of different depths, available N was found maximum at 10-15 cm depth in all the land uses except for burnt chir pine forest. The nitrogen content increased by 0.70 to 3.17 % in burnt sites, and 0.47 to 1.17 % in unburnt chir pine. Available P and K were observed to increase infinitesimally after one year of controlled fire in all the land uses in all three depths. Highest increase of 5.76 % in available P was found under burnt chir pine forest and grassland soil at 10-15 cm depth and 5-10 cm soil depth, respectively, whereas lowest increase was found under control one (0.84 %) (Figure 4).

In burnt chir pine forest, grassland and scrubland soil (Figure 1, 2, 3), % increase in available potassium was found highest at 5-10 cm soil depth viz. 1.27 %, 1.84 % and 1.06%, respectively. In unburnt chir pine, highest % increase (0.77 %) was observed at 10-15 cm soil depth (Figure 4). The data on soil nutrient content post-fire revealed that controlled fire had positive impact on available N, P and K. Weston and Attiwill (1990) reported similar results who observed increase in N after 200 days of controlled fire. However, Fisher and Binkley (2000) reported decrement in available N following fire because of some loss through volatilization. Serrasolsas and Khanna (1995), Romanya *et al.* (1994) and Macadam (1987) reported that fires resulted in an enrichment of available P. Similarly, Lavoie *et al.* (2010) and Shakesby *et al.* (2015) found that prescribed fire resulted in an increase in available K. After prescribed fire, an increase in nutrients in the mineral soil was found (Kennard and Gholz, 2001; Úbeda *et al.*, 2005; Shakesby *et al.*, 2015; Alcañiz *et al.*, 2016) due to two reasons: 1. Formation of and its further incorporation into the soil and 2. Release of basic cations from the soil organic matter. Inorganic N content was found higher in burnt sites over unburnt sites (Singh and Singh, 2014). Increase in available potassium post-fire in upper layers of soil was reported by Kumar *et al.* (2013).

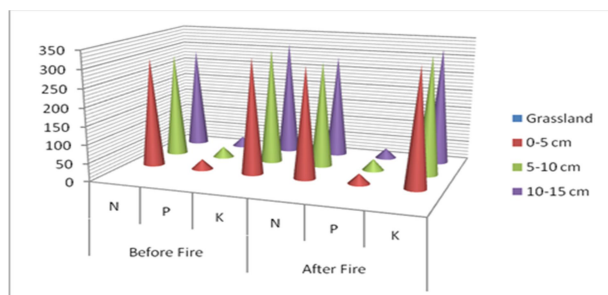
### Fire effects on soil physico-chemical properties

#### Organic C

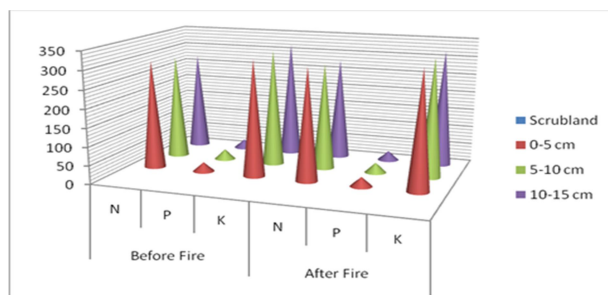
After one year of experimental fire, there was a slight decrease in soil organic C in comparison to initial levels. At 0-5 cm depth, highest % decrease in organic C was found under burnt chir pine forest (1.63%) (Figure 5), whereas lowest decrease of 0.76 % was found under scrubland soil (Figure 7). At 5-10 cm depth, % decrease in organic C was found highest under scrubland (3.28%) which differs slightly from grassland (2.46%) after one year of controlled fire. Lowest decrease of 0.86 % was found under burnt chir pine forest. At 10-15 cm soil depth, grassland soil (1.68%) was found to have highest decrease in organic C (Figure 6), whereas lowest decrease was found under scrubland (0.85%) (Figure 7). In unburnt chir pine forest (control), organic C was found to increase in all three depths at the end of experiment (9.76% in



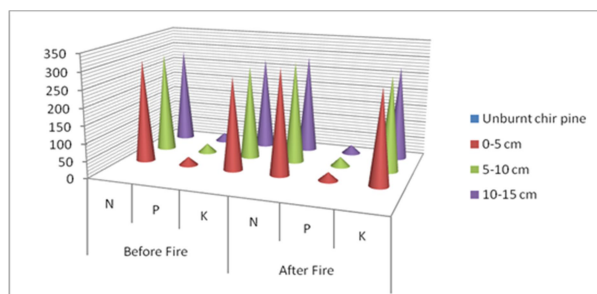
**Figure 1: Available nutrient content in chir pine forest before and after fire**



**Figure 2: Available nutrient content in grassland before and after fire**



**Figure 3: Available nutrient content in scrubland before and after fire**



**Figure 4: Available nutrient content in unburnt chir pine forest before and after fire**

0-5 cm, 7.76% in 5-10 cm and 11.4% in 10-15 cm soil depth). The data on organic C inferred that controlled fire did not alter organic C content drastically, however, it was slightly lower than pre-

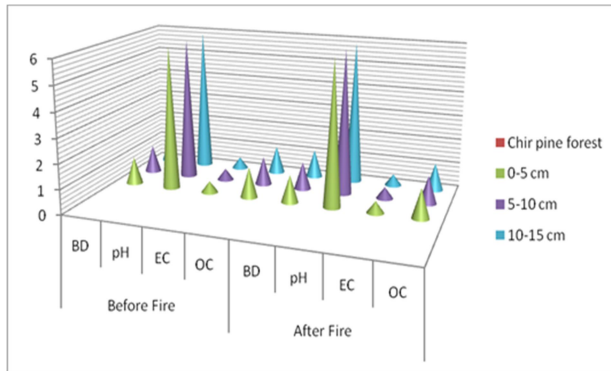
fire level. Decrement in soil organic C content was ephemeral. This corroborates the findings of Andreu *et al.* (1996) and Johnson and Curtis (2001) who found that less intense prescribed fire may cause little loss in soil C initially as compared to unburnt site, but may result in later gains due to the addition of unburned residues with time (including charcoal). Chandra and Bhardwaj (2015), Verma *et al.* (2019) and Jhariya and Singh (2021) also reported lower levels of soil organic C in burnt sites over unburnt sites. However, Úbeda *et al.* (2005) and Granged *et al.* (2011b) reported no significant alteration in soil organic C content after controlled fire.

### Bulk density

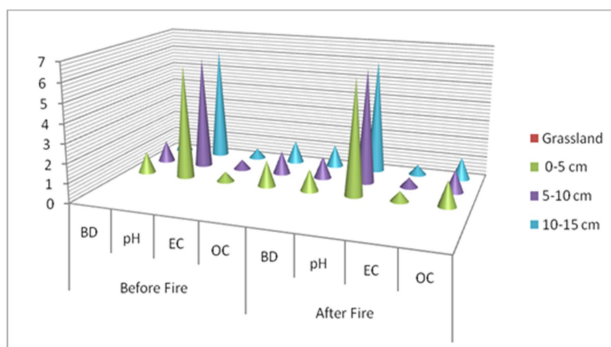
After controlled burning, bulk density in all the land uses was found to increase extremely small i.e. less than 1 %, except for grassland (1.74%). Highest % increase in bulk density was found in grassland at 5-10 cm soil depth. Overall, change in bulk density was found non-significant under all land uses (Figure 5, 6, 7). Similar results were reported by some other scientists (Phillips *et al.*, 2000; Grady and Hart (2006); Pierson *et al.* (2008); Meira-Castro *et al.*, 2014) who reported that bulk density did not differ significantly after prescribed fires.

### Electrical conductivity and Soil pH

After one year of controlled fire, an infinitesimal increase in electrical conductivity of soil was observed in all the land uses (Figure 5, 6, 7) i.e. 2.14% in burnt chir pine forest, 1.92% in grassland and 1.84% in scrubland, except for unburnt chir pine forest. At 10-15 cm depth, in scrubland and unburnt chir pine forest, EC was found to decrease by -1.85% and -2.12%, respectively. This corroborates the findings of other scientists who reported that electrical conductivity was slightly increased after fire in burnt plots than in unburnt plot due to the release of inorganic ions from the combusted soil organic matter (Naidu and Srivasuki, 1994; Hernandez *et al.*, 1997 and Verma *et al.*, 2019). Soil pH was found to increase in all land uses post-fire. When different land uses were compared for 0-5 cm depth (Figure 5,6,7), highest increase was observed under burnt chir pine forest and lowest was observed under scrubland, whereas, no change was observed under control one. Our results were supported by the findings of Arocena and Opio (2003), Scharenbroch *et al.* (2012);



**Figure 5: Soil physico-chemical properties in chir pine forest before and after fire**



**Figure 6: Soil physico-chemical properties in grassland before and after fire**

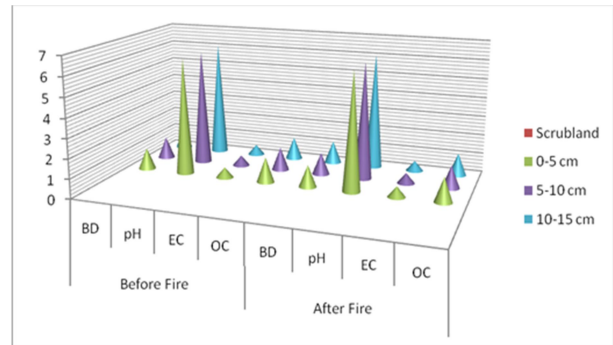
Switzer *et al.* (2012) and Verma *et al.* (2019) who observed post-fire increase in soil pH due to burning of fuel and the consequent release of bases. On the contrary, Meira-Castro *et al.* (2014) and Alcaniz *et al.* (2016) reported that pH values remain unaltered post-fire.

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## Soil texture

The texture of soil after the fire season (12 months) remained the same and was worked out to be gravelly silty clay loam. The research findings of Pierson *et al.* (2008) also supported our results.



**Figure 7: Soil physico-chemical properties in scrubland before and after fire.**

## Conclusion

We concluded that controlled fire causes slight alterations in nutrient content and organic C of soil and that too for a shorter period of time in comparison to wildfires. Therefore, controlled fire can be used as a management tool for controlling wildfires which otherwise can cause a huge damage to fauna, flora and also results in environment pollution.

## Conflict of interest

The authors declare that they have no conflict of interest.

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